The Southern Forest Resource Assessment

Summary Report

by

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PREFACE

The Southern Forest Resource Assessment was initiated in 1999 as a result of concerns raised by natural resource managers, the science community, and the public regarding the status and likely future of forests in the South. These included changes to the region's forests brought about by rapid urbanization, increasing timber demand, increasing numbers of satellite chipmills, forest pests and changing air quality. In response to these issues, leaders of four of the region's federal natural resource agencies (USDA Forest Service, U.S. Environmental Protection Agency, U.S. Fish and Wildlife Service), and the Tennessee Valley Authority, agreed to work together to provide a careful evaluation of the overall condition and ongoing changes of southern forests. State forestry and fish and wildlife agencies were invited to take part and have actively contributed to the effort. The USDA Forest Service, through the Southern Region and Southern Research Station, has provided overall leadership.

The Draft Assessment Report and this Summary Report are the culmination of more than 2 years of effort by more than 25 scientists and analysts from the above agencies as well as southern universities. More than 100 scientists from universities, state and federal agencies, industry and conservation organizations provided peer reviews to enhance the reports' accuracy and completeness. This Summary Report is intended to provide its reader with an overview of the many forces of change affecting southern forests and the changes they affect. It summarizes the detailed results reported by Assessment Team members in individual Chapters of the full Draft Assessment Report. The information contained in the body of the Assessment should enhance public understanding of southern forests, inform public debate, and improve public policies that result.

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1 Introduction

The South's forests are expansive, diverse, and vital. Many forces—ranging from development to environmental change to timber management—continue to shape them. Although change has been constant, the rate of change is accelerating and has raised questions about the sustainability of southern forests and the broad complement of values they provide.

Sustainability is a sweeping concept—ensuring opportunities for the future as resources are used today. Pursuing sustainability requires broad and long-term commitment and ongoing monitoring, study, and action. The first step is to understand and anticipate the forces of change that will directly shape forested ecosystems and the social factors that are likely to drive those changes. Ultimately, society must manage change to achieve sustainability.

The ***Southern Forest Resource Assessment*** documents and analyzes the many factors that are affecting the forests of 13 Southern States (Figure 1.1). Our goal has been to answer several specific questions about southern forests and their uses, and in the process, to create a comprehensive base of information about them. This undertaking is complex given the multiple factors that influence forests, the diversity of the region's people and biota, and the history of land and resource uses.

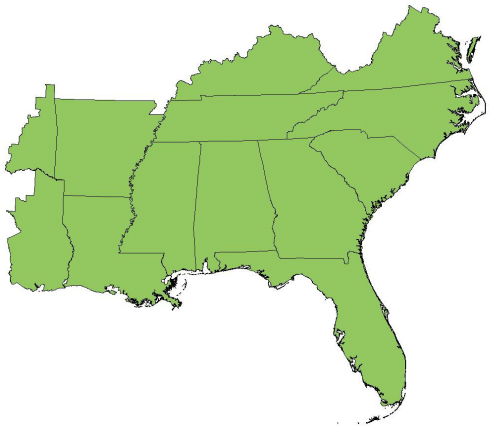

Figure 1.1—The region examined by the Southern Forest Resource Assessment.

The South has a strong regional identity that is shaped in large part by its agrarian past and the predominantly private ownership of its land. With more than 5 million private owners controlling

89 percent of southern forests, forest area and conditions are influenced by diverse landowner interests and objectives. An ever-changing patchwork of forest uses and conditions has resulted.

Not surprisingly, interest in these forests extends far beyond landowners to all who use their varied goods and services. As organizers of this Assessment, we have tried to convene these many interests, elucidate and analyze their concerns with science and data, and present findings in a useful way (Figure 1.2). Monitoring change at a broad, multi-State scale and describing cumulative changes is a logical and important role for government in the area of private forestry.

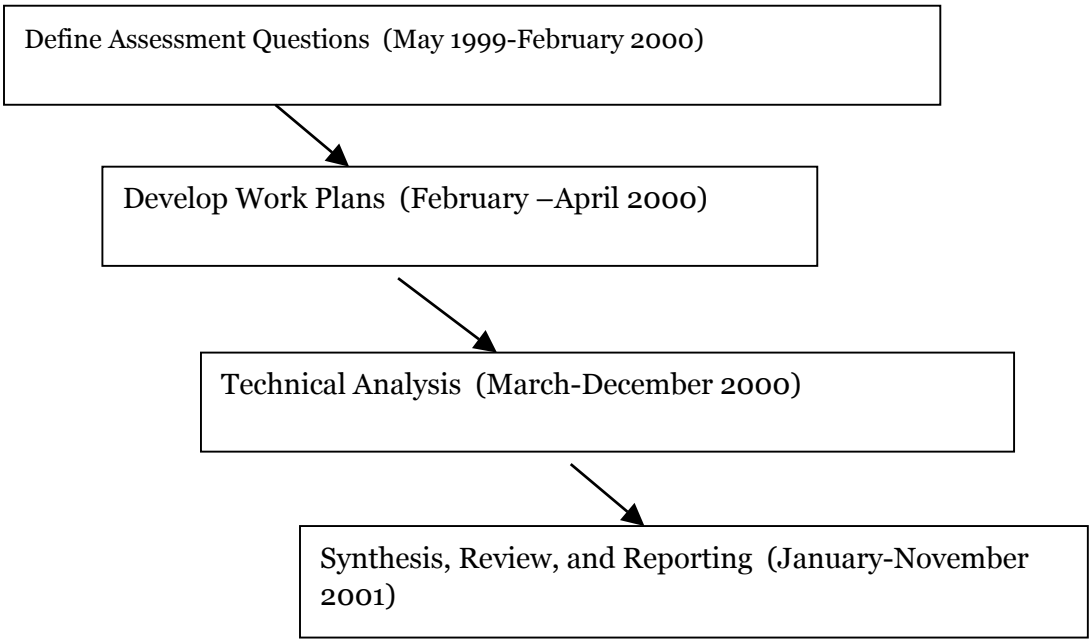

Figure 1.2—Flow chart of the Southern Forest Resource Assessment Process.

This Assessment was organized around 23 questions that summarized public concerns about southern forests and their uses (Table 1.1). These questions were refined during a process that involved considerable public review in venues ranging from large meetings to one-on-one discussions. More than 750 people participated in the meetings; hundreds more provided written input. Once the questions were finalized, a rapid scientific assessment process was developed and employed to address each using available knowledge and data. Each question was addressed by subject experts who comprised the Assessment Team, and their work is presented as individual chapters in the Assessment's Technical Report. Data used in the Assessment has been assembled and made available through a public Web site. This report synthesizes and provides some interpretation of the detailed information contained in the Technical Report, but does not provide an exhaustive compilation of all of its findings.

Table 1.1—Major questions addressed during the Southern Forest Resource Assessment. Each question is addressed in a chapter of the technical report. The chapter label is used to refer to these Chapters in this summary document.

Chapter	Assessment question
TERRA-1	What are the history, status, and projected future of terrestrial wildlife habitat types and species in the South?
TERRA-2	What are the history, status, and projected future of native plant communities in the South?
TERRA-3	What are the likely effects of expanding human populations, urbanization, and infrastructure development on wildlife and their habitats?
TERRA-4	What are the historical and projected future impacts of forest management and access on terrestrial ecosystems in the South?
TERRA-5	What conditions will be needed to maintain plant and animal species associations in the South?
SOCIO-1	How have land uses changed in the South and how might changes in the future affect the area of forests?
SOCIO-2	What are the attitudes and values of southern residents toward forests and their management and how have they changed over time and do they differ by demographic groups?
SOCIO-3	How do current policies, regulations, and laws affect forest resources and their management?
SOCIO-4	What motivates private forest landowners to manage their forest land and how are their management objectives formed?
SOCIO-5	What role do forests play in employment and local economies in the South?
SOCIO-6	What are the supplies of and demands for forest based recreation and other noncommodity uses of forests in the South?
SOCIO-7	How do forests and their uses influence the quality of life in the South?
TIMBR-1	What are the history, status, and projected future demands for and supplies of wood products in the South?
TIMBR-2	What are the status and trends of forest management practices in the South?
TIMBR-3	How might existing and new technologies influence forest operations and resultant conditions of forests?
HLTH-1	What are the history, status, and projected future of southern forests?
HLTH-2	How have biological agents including insects and disease influenced the overall health of the South's forests and how will they likely affect it in the future?
HLTH-3	How have abiotic factors including environmental stressors such as air pollution influenced the overall health of the South's forests and what are future effects likely to be?
AQUA-1	What are the history, status, and likely future of water quality in southern forested watersheds?
AQUA-2	What are the history, status, and likely future of forested wetlands in the South?
AQUA-3	How have forest management activities and other forest uses influenced water quality, aquatic habitat, and designated uses in forested watersheds?
AQUA-4	What are the implementation rates and effectiveness of BMP's in the South?
AQUA-5	What are the history, status, and likely future of aquatic habitats and species in the South?

The Assessment effort was designed by participating agencies as a two-tiered approach. The Summary Report and the Technical Report represent the first tier, a broad comprehensive assessment of resource questions. The second tier will begin by identifying small areas within the South for additional study at finer scales. Findings from the broad scale assessment will be used to identify areas where forces and implications of change are currently strongly focused or are

expected to be strongly focused. The number of subregional assessments sponsored by the Assessment will depend on availability of funding and other resources. Specific questions to be addressed will be determined by the issues faced in each area and will be defined at a later date. In addition, the findings of the Assessment coupled with the identification of small areas may prove useful for focusing the efforts of future researchers.

In the sections that follow, we examine how several forces of change have shaped and may continue to shape the forests of the South. Forces of change include social, biological, and physical forces. We then examine the history, status, and possible future of southern forests in four different dimensions: social and economic systems, forest area and conditions, terrestrial ecosystems, and aquatic ecosystems. We conclude by examining the broad implications of these findings and list major knowledge gaps and scientific uncertainties.

Throughout the sections that follow, the Technical Report is the source of all of our findings. Accordingly, individual sections that follow refer to the specific chapters in the Technical Report from which the findings are drawn, using the naming convention shown in Table 1.1. For example, SOCIO-1 refers to the first chapter in the Social and Economic Systems section, which addresses the question: "How have land uses changed in the South, and how might changes in the future affect the area of forests?" Each section is keyed to the chapters that are primary sources of findings. The individual chapters provide in depth analysis of the issues and extensive citations to primary references on each topic and should be reviewed for more detailed information.

2 Forces of Change

Several forces have shaped and continue to influence the extent, structure, and function of the South's forests. We summarize these forces using five categories: (1) land markets that ultimately determine the area of forests; (2) timber markets that influence the location and extent of timber harvesting, management approaches, and forest conditions; (3) social institutions that organize the behavior of people who own, manage, and use forests in the region; (4) biological factors such as insects and diseases that affect the structure of forests; and (5) physical factors that affect the structure of forests, including hurricanes, fire, and ice storms, as well as the ambient environment.

2.1 Forecasting Change

Throughout the Assessment, we place emphasis on understanding historical change and ongoing trends. We also evaluate possible futures. Forecasting changes in forest ecosystems and the values that derive from them is necessarily fraught with uncertainty. Forests and linked social systems change in response to multiple factors. Current trajectories of change often reflect the legacies of historical land use and resource management. Some past actions have irreversible consequences, such as the hydrologic effects of dams. In other cases, altered ecosystems may be restored or renewed. In all situations, the future of forested ecosystems will be the product of the working and adaptation of complex systems and the impacts of unanticipated events.

We use an integrated modeling system to forecast timber harvesting, forest investment, forest growth, and land use up to the year 2040. This system, called the Southeastern Regional Timber Supply Model is described in TIMBR-1. It incorporates the land use model described in SOCIO-1. Forecasting these outcomes requires that we make assumptions about the future course of certain core variables. Three key assumptions are:

(1) Demand for timber products is projected to increase at the rate of 1.6 percent per year. This is the demand projection developed for the South in the most recent Resources Planning Act assessment (see TIMBR-1), and is based on trends in macroeconomic variables such as Gross National Product and population as well as on trends in international timber markets.

(2) Population and income growth projections are those used by the U.S. Global Change Program (see SOCIO-1). These projections are constructed at the county level and hold especially strong influence on projections of land uses.

(3) The timber productivity of pine forests is based on the expected adoption of management activities. Projected adoption rates for industrial and nonindustrial private forests are taken from expert surveys of industrial owners and States respectively (see TIMBR-3).

As with any forecasting exercise, assumptions play a large role in outcomes. To understand the sensitivity of models to these assumptions, models were run with alternative scenarios. These are discussed in detail in the TIMBR-1 and SOCIO-1 chapters. In this Summary Report we refer strictly to the base scenario constructed with the assumptions described above. Sensitivity analysis reveals that future land uses and forest conditions are especially sensitive to assumptions regarding timber demand and productivity growth. For example, weaker demand growth would lead to lower prices, less harvesting, and less area of forest than projected for the base scenario. If timber productivity growth were not realized, then timber prices and the area of planted pine could be substantially higher than was projected for the base scenario.

In the discussions that follow, we attempt to estimate the direction of change and, in some case, explicitly forecast future conditions. These forecasts explore possible futures and project the potential consequences of ongoing and anticipated changes. They should be viewed as “what could happen,” rather than “what will happen.”

2.2 Land Markets

Primary Question:	SOCIO-1: How have land uses changed in the South and how might changes in the future affect the area of forests?
Related Questions:	AQUA-2: What are the history, status, and likely future of forested wetlands in the South?

Private land dominates the southern landscape, and land use is determined by the decisions of individuals and firms as they attempt to put land to profitable and satisfying uses. Land use has changed substantially over the past three centuries, and it continues to change. In many areas, extensive agriculture gave way to forest succession beginning in the early part of the 20th century. Today, rapid economic and population growth are fueling urbanization and low-density residential development in many parts of the South. Where urban land uses do not dominate, rural land may switch between agriculture and forest cover depending on the prices paid for agriculture and timber products. Historical patterns reveal that some forests are cleared as agricultural prices increase, and marginal cropland and pasture are planted in forest cover as agricultural prices fall.

Our analysis of historical land use change found that:

- In the period following European settlement (1780 to 1930), land clearing for agriculture and timber production completely restructured southern ecosystems. Legacies of these massive alterations still influence forest structure, many forest functions, and aquatic systems. For example, severe soil erosion and sedimentation of waterways strongly altered and continue to influence aquatic habitat and species, especially mussel and fish species.

- Land clearing for agriculture greatly diminished the area of forested wetlands in the South. In the Mississippi River Valley, for example, more than 80 percent of bottomland forests have been converted to agriculture since European settlement (AQUA-2).

We analyzed more recent land use changes and the factors that drive them (SOCIO-1) and found that:

- There has been essentially no net change of total forest-land area since the 1970's (Figure 2.1), and current forest area equals about 91 percent of that recorded in 1907. However, this stability at the regional level is the result of large offsetting subregional changes: much forest has been converted to urban and agricultural uses, and agricultural land has been converted to forests through natural reseeding and tree planting.

- The rate at which rural land (both forest and agricultural) has been developed for urban and industrial uses in the 13 Southern States increased from about 667,000 acres per year between 1982 and 1992 to about 1.1 million acres per year between 1992 and 1997. Urbanization is forecast to continue at the rate of 1.1 million acres per year through the year 2020. The source of new urban uses is both agricultural and forest land.

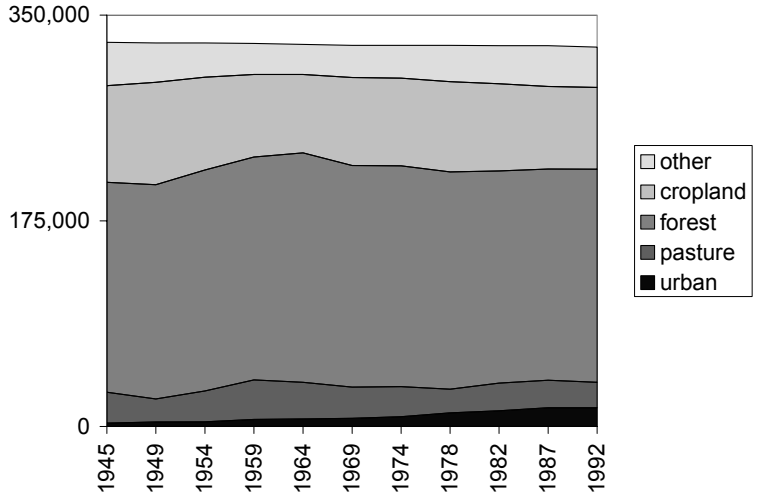

Figure 2.1—Land use shares by type for Southern States, 1945 to 1992 (note that Texas and Oklahoma are not included). Source: SOCIO-1, Figure 1.

- According to forecasting models described in SOCIO-1, the South could lose about 12 million forest acres (about 8 percent of forest land) to urbanization between 1992 and 2020. These losses are forecast to be concentrated in a few places: the Piedmont and Mountain areas of North Carolina, adjacent Piedmont areas of South Carolina and Georgia, forested areas of northern Florida including the Panhandle, and the Atlantic and Gulf coastal areas. Smaller areas with high rates of loss would include the forests around the cities of Nashville and Birmingham and in northern Virginia between Washington and Richmond (Figure 2.2). An additional 19 million acres of forest are forecast to be developed between 2020 and 2040.

- Forecasts indicate that agricultural land will continue to be converted to forest in other parts of the South as rising timber prices encourage tree planting. Forest gains from these sources are projected to be about 10 million acres between 1992 and 2020. Total forest area is forecast to increase in the Coastal Plain of southwestern Georgia and in a small area centered on the border between eastern North Carolina and Virginia. The largest area of potential forest gains however, is in the lower gulf Coastal Plain, including large portions of Arkansas, Mississippi, and Louisiana (Figure 2.2). An additional 15 million acres of agricultural land are forecast to be planted to forest between 2020 and 2040. The net result of these changes is a westward shift in forest distribution.

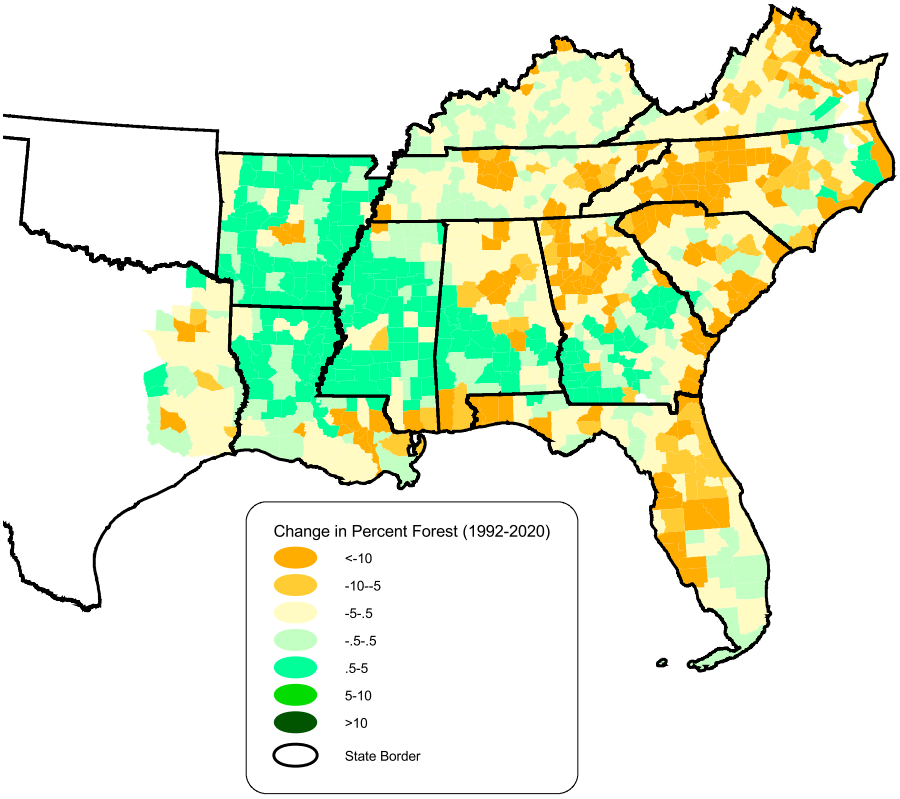

Figure 2.2—Base scenario forecasts of changes in percentages of land in forest by county for 1992-2020. Source: SOCIO-1, Figure 11.

2.3 Timber Markets

Primary Question:	TIMBR-1: What are the history, status and projected future demands for and supplies of wood products in the South?
Related Questions:	TIMBR-2: What are the status and trends of forest management practices in the South?
	TIMBR-3: How might existing and new technologies influence forest operations and resultant conditions of forests?

The South, particularly the Coastal Plain and the Piedmont, contains the most intensively managed forests in the world. This one region of the United States produces more wood products than any other single nation. Timber harvesting, tree planting, and other forest investments have increased and forest inventories have expanded as harvesting and processing technologies have changed in

ways that favor southern timber. Over the past several years, changes in processing technology and in the location of large processing facilities (for example, chip mills and oriented strand board mills), have changed the intensity of timber harvesting within subregions of the South.

We examined changes in the world's timber markets and technology, searching for probable effects on markets for the South's forest products (TIMBR-1, TIMBR-2, and TIMBR-3). We found that:

- Wood production continues to be an important part of the U.S. economy. The United States is the world's largest producer, consumer, and importer of wood products. It is also the second largest exporter of wood products after Canada.

- Technology, public policy, and forest growth have all combined to enhance the South's position and share of the forest products markets. Technology has allowed smaller diameter trees and a wider variety of species to be used in wood products. Public policies have reduced timber harvesting from public land, which is concentrated in the Western United States.

- Forest regeneration and growth have expanded southern timber inventories by 73 percent since the 1950's, and strong timber markets have encouraged landowners to keep land forested. As a result of these and other factors, the South's timber production more than doubled between 1953 and 1997. Its share of U.S. production rose from 41 to 58 percent and its share of the world's production from 6.3 to 15.8 percent (Figure 2.3).

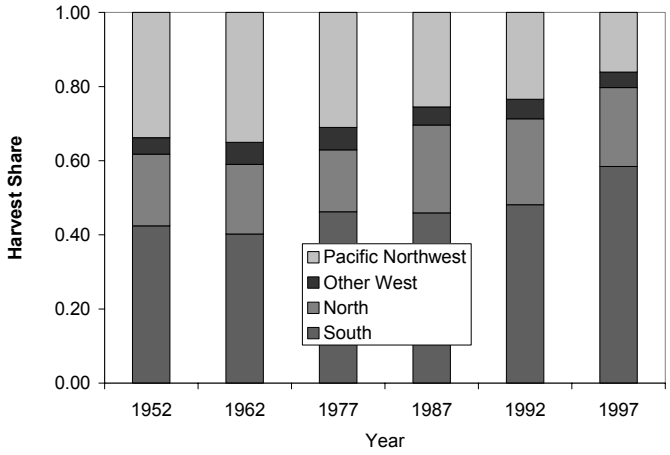

Figure 2.3—Shares of timber harvest volumes, by region of the United States, 1953 to 1997. Source: TIMBR-1, Figure 6.

- The South provides a great variety of timber products, with no single product dominating. Softwood sawlogs represent the largest product share at 28 percent of total output. Softwood pulpwood and hardwood pulpwood now account for 25 and 16 percent of output, respectively (Figure 2.4).

- Since 1953, hardwood pulpwood has experienced the greatest increase in product share, growing from 3 to 16 percent of output. This increase reflects a change in pulping technology that allowed hardwoods to be substituted for more expensive softwoods in the manufacturing of paper products.

- Models described in TIMBR-1 forecast that timber production in the United States will increase by roughly a third between 1995 and 2040. Nearly all production increases will come from the South. The South's timber production is forecast to increase by 56 percent for softwoods and by 47 percent for hardwoods between 1995 and 2040 (Figure 2.5).

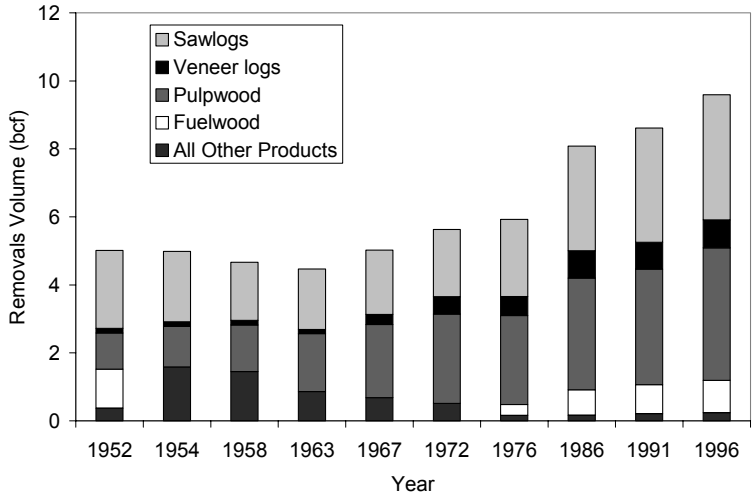

Figure 2.4—Removals by destination product, South-wide, all species, 1953 to 1996. Sources: TIMBR-1, Figure 14. Note: Data for 1954to 1972 on "All Other Products" include fuelwood.

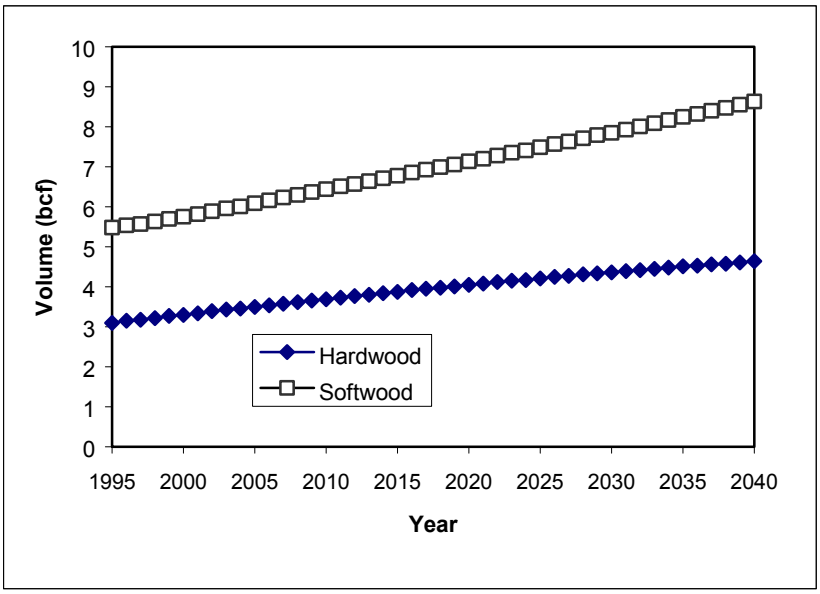

Figure 2.5—Subregional Timber Supply Model projections of total hardwood and softwood removals volumes, in billion cubic feet (bcf), by private owners (where NIPF stands for nonindustrial private forest land), 199 to 2040, under the base scenario. Source: TIMBR-1, Figures 24 and 29.

Changing wood manufacturing technologies have altered the type and size of timber materials demanded and the location of processing and harvesting (Figure 2.6). An example is chip mills, which have generated debate about timber harvesting in the South. Chip mills sometimes lead to harvesting in areas not previously subject to harvesting. Before the 1990's, pulpmills and manufactured wood panel mills relied heavily on remote log concentration yards and maintained large chipping facilities at the site of panel and pulp manufacture. Today pulpwood-sized logs increasingly are chipped away from the mill as needed. Per unit of volume, moving wood in chipped form is cheaper than moving pulp logs, providing a significant economic benefit to pulpwood consumers and log producers (TIMBR-1). Harvesting in new areas also leads to changes in local forest conditions that can change wildlife habitat and landscape aesthetics (TERRA-4 and SOCIO-7). However, wood products markets are highly integrated, so it is very difficult to isolate the effects of this or any other technological component from all other demand and supply factors.

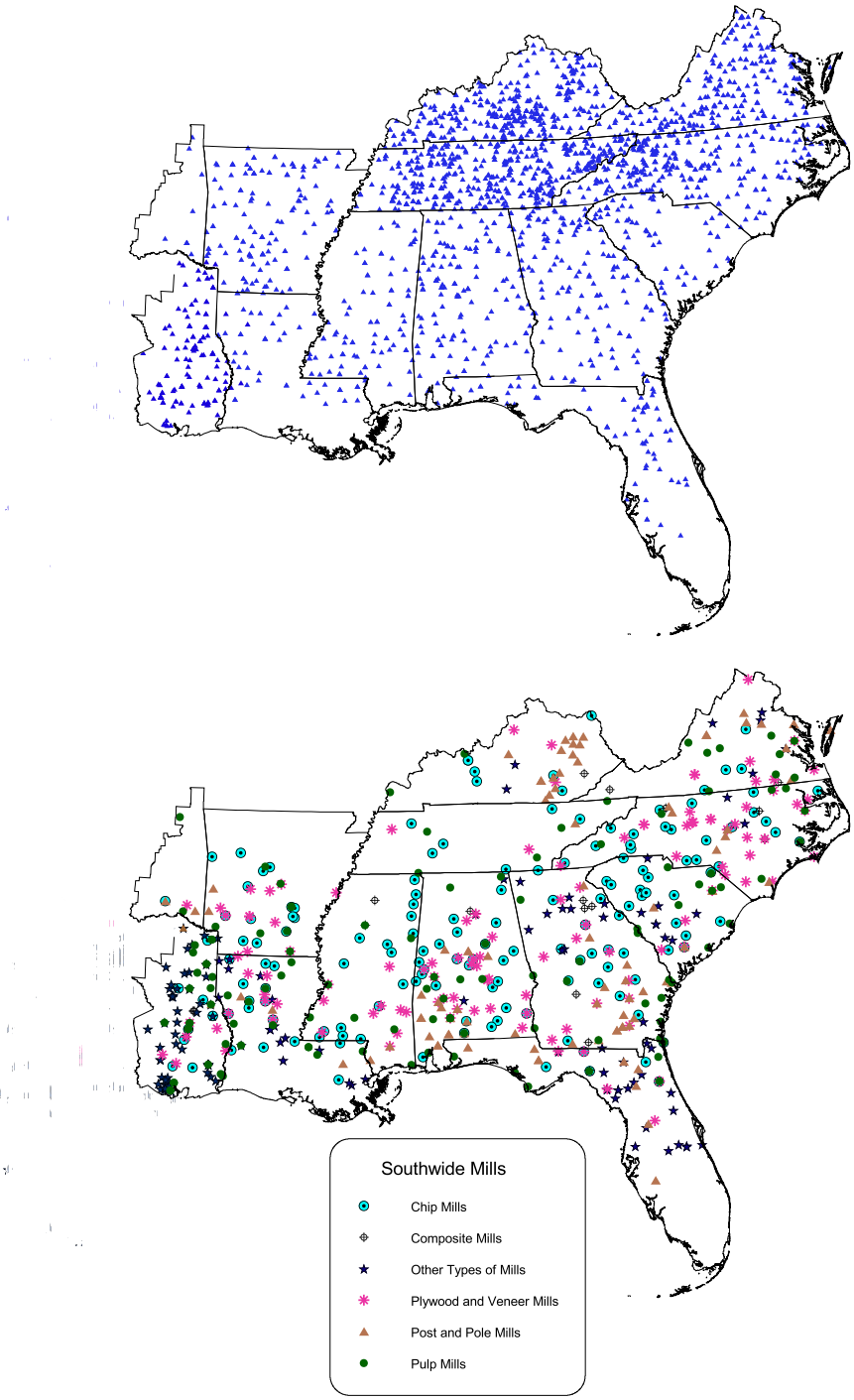

Figure 2.6—Locations of (a) sawmills (b) all other mills in the South. Source: TMBR-1, Figures 10-12.

Data on chip mill output is limited to recent years. Chip mills processed about 27 percent of pulpwood in the South in 1999. They produced 47 million green tons of chips in 1998, 45 million green tons in 1999, and 39 million green tons in 2000. In 1999, 42 percent of the material processed in chip mills was softwood and 58 percent was hardwood (TIMBR-1).

2.4 Social Institutions

Primary Question:	SOCIO-3: How do current policies, regulations, and laws affect forest resources and their management?
Related Questions:	AQUA-4: What are the implementation rates and effectiveness of Best Management Practices (BMP's) in the South?

Various social institutions organize people's use of land and resources and therefore affect the structure of forests. Laws and regulations define objectives and prescribe administrative procedures for management of public land. Laws passed by various jurisdictions also influence management of private forest land. Public programs administered through resource management agencies can influence the management and structure of the region's forests.

We evaluated the influences of various social institutions on forest uses and forestry decisions in the South. We analyzed effects of taxes, land use regulations, government subsidies, and forest management standards (SOCIO-3) and found that:

- The current income tax code has mixed impacts on long-term investments in forestry; inheritance taxes can encourage forest liquidation and land parcelization.

- Incentives programs that subsidize tree planting on private land have a long and successful history in the South. This suggests that subsidies can increase forest area and change forest conditions. New programs with explicit wildlife and environmental objectives now complement the older programs that focused exclusively on timber production.

- In urbanizing areas, a proliferation of local regulations affecting land use and forest management can be seen as one reaction to forest losses and to increasing scarcity of green space. Local regulations affecting forest uses more than doubled in the South between 1992 and 2000. Expanding populations and development will likely continue this trend. Regulatory uncertainty can discourage long-term investments in forest land.

- While still influencing a relatively small portion of the region, conservation easements and outright purchases of important habitats are becoming increasingly common in the South. This approach can be used to protect wildlife habitats at broad scales on private landscapes.

- Direct regulation of forestry is limited in the rural South. States generally rely on voluntary Best Management Practices (BMP's) to protect water quality (AQUA-4).

- A combination of factors—including strong markets, private ownership, good market information, and widespread mitigation of wildfire risk—has generated a positive environment for forest investment in the South. A strong competitive advantage explains the large investments wood products industries have made in forests and processing capacity in the South (SOCIO-5). Investment opportunities for intensive forest management and wood product manufacture have improved relative to other regions of the United States, especially over the last 15 years (TIMBR-3).

2.5 Biological Factors

Primary Question:	HLTH-2: How have biological agents including insects and disease influenced the overall health of the South's forests and how will they likely affect it in the future?
Related Questions:	TERRA-3: What are the likely effects of expanding human populations, urbanization and infrastructure development on wildlife and their habitats?

Ecological systems are often restructured from within. For example, natural succession favors the replacement of pioneer species with shade tolerant species. Insect populations can shift from endemic to epidemic status and quickly kill a substantial share of overstory trees. Plant diseases reduce vigor or cause localized mortality and selectively remove certain plant species from the forest. Regeneration and growth that follow mortality can change the species composition of the subsequent forest.

While pathogens, insects, and mortality are natural components of forested ecosystems, land use and management can alter their effects. Introduced exotic species, which are prevalent in the South, can completely displace native plant and animal species, thereby restructuring forest ecosystems. Cultivating tree species beyond their natural range and altering forest composition can predispose forests to insect and disease outbreaks. Conversely, management strategies and direct intervention can mitigate the spread of and damage caused by these outbreaks.

The Assessment evaluated the dynamics of several biological agents that have had or will likely have a substantial impact on forest ecosystems or the values that people derive from them (HLTH-2). We found that:

- In general, the dynamics of native disease agents and native insects are heavily influenced by the availability and condition of host materials. For those disease agents and insects that target pine species, the concentration of pine forests in some subregions has increased the availability and contiguity of host material (see Figure 2.7). Mortality caused by insects and

diseases, especially southern pine beetle and fusiform rust, could increase commensurate with the expected increase in pine plantations, but this will depend on the degree of management.

- Exotic plants (trees, shrubs, and vines) and animals (birds and mammals) are having large impacts on forested ecosystems. Expanding urban areas will increase the impact of domestic animals on wildlife (TERRA-3).

- Exotic pathogens and insects generally have a greater potential to restructure forested ecosystems, especially hardwood forests, than do native species because natural enemies of exotic species are absent or control methods are ineffective at broad scales.

- The impacts of exotic pests are expected to grow as a conservation concerns in the South. Multiple exotic insects, such as gypsy moths, and exotic diseases such as dogwood anthracnose, will especially influence hardwood forest types in the northern portions of the region. An insect, the balsam wooly adelgid, interacting with environmental stressors is causing tree mortality and altering habitat values in the rare spruce-fir ecosystem of the South.

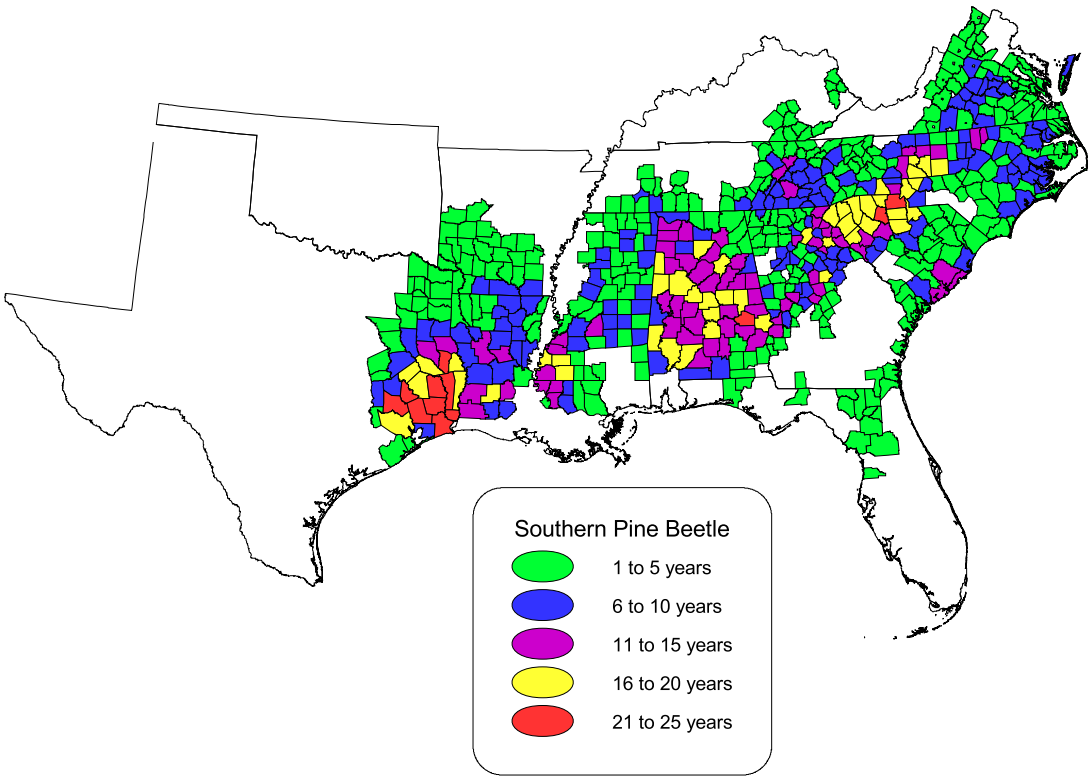

Figure 2.7—Counties in outbreak status for southern pine beetle; a 40-year summary Source: HLTH-2, Figure 7.

2.6 Physical Factors

Primary Question:	HLTH-3: How have abiotic factors including environmental stressors such as air pollution influenced the overall health of the South's forests and what are future effects likely to be?

Southern forests have evolved under the influence of a number of physical disturbances. Among the most important is fire. Fire-adapted ecosystems are maintained by frequent, low-intensity fires but may be substantially altered by intense fires. The suppression of fire—an objective of public forestry programs throughout much of the 20th century—has altered these systems. The effective use of fire in forested ecosystems is an ongoing challenge for forest managers as humans continue to populate forested areas and safety and smoke management concerns restrict burning options.

Wind-related disturbances also influence forests in much of the South. Hurricanes alter forest structure over large areas of the Coastal Plain and Piedmont and microbursts and tornadoes create smaller openings throughout the region. Ice storms limit the northern range of some tree species.

In addition, the growth, development, and species composition of forests depend on the ambient environment. Alterations to the environment, especially through air pollutants such as atmospheric ozone have the potential to affect forest health and vigor. The natural geographic range in which forest species occur and thrive can be influenced by temperature and moisture regimes. Some model scenarios forecast that potential climate changes could alter the ranges of commercially and ecologically important species. There are some ecotypes that may be especially sensitive to small changes in climate and environment.

We examined trends and potential future conditions for various physical stressors in the South (HLTH-3). We found that:

- While effects are variable, acid deposition does not pose a significant threat to forest vegetation or to stream chemistry through a vast majority of the South. The major exception is the Southern Appalachians where, because of soil conditions, increased acid deposition derived from oxides of nitrogen is expected to alter plant communities and stream chemistry.

- Ozone pollution is forecast to increase anywhere from 20 to 50 percent between 1990 and 2025, but concentrations are and will continue to be highly variable across the South (Figure 2.8). Ozone has reduced and will continue to reduce the growth rates of pine species in the South and future ozone damage could be exacerbated by a warming climate.

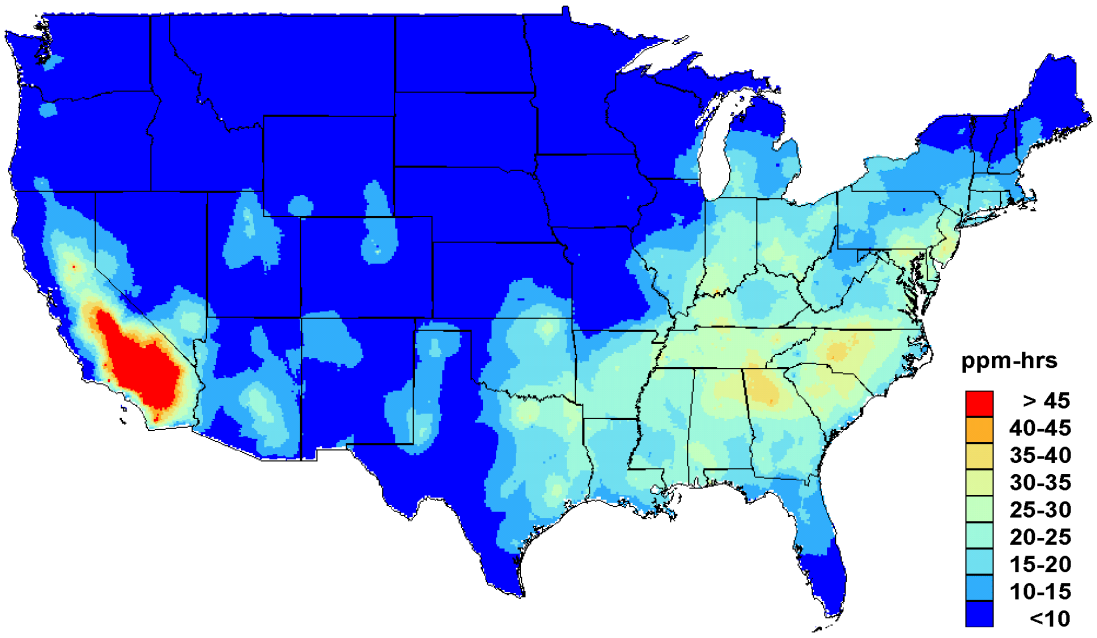

Figure 2.8—Three-month maximum daily ozone exposure for 1990 showing spatial variability in ozone concentrations. Source: HLTH-3, Figure 4.

- Atmospheric carbon (CO_2) is expected to rise throughout the 21st century and current models forecast a resulting increase in air temperatures. Overall, the moderate increases that are projected would enhance the growth of trees in the South. However, these models suggest that if temperatures were to rise somewhat more than expected, then the area and the productivity of forests would decline. These changes are uncertain and could vary across the region.

- There is a high degree of uncertainty about the direction and magnitude of forest impacts from projected climate changes due to the importance of interactions among precipitation, air temperature, and forest growth.

- Various studies show that there could be a general increase in the number and/or severity of extreme weather events with climate change. However, we lack the knowledge to predict with confidence the future magnitudes of these changes.

- Southern forests could play an important role in sequestering atmospheric carbon (Figure 2.9), which could aid in mitigating the negative effects of climate change.

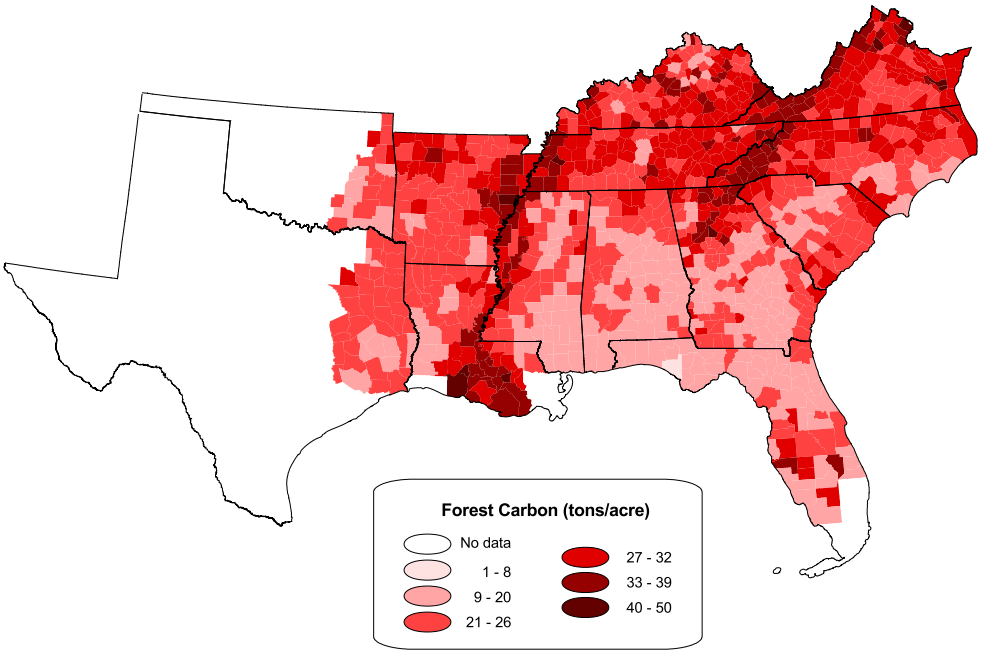

Figure 2.9—Total aboveground carbon per acre in southern forests. Source: HLTH-3, Figure 10.

2.7 Interactions

The forces of change described here rarely act alone in their influence on the South's forests. Rather, they interact and often have compounding effects. The population dynamics of insects can be influenced by climatic factors. For example, drought is linked to southern pine beetle outbreaks. Pollutants such as ozone may worsen the damage caused by insects. Land use changes may shift forests toward developed uses. Increased human populations bring greater potential for invasive and aggressive exotic plants and animals, which can result in displacement or loss of native species. Increased scarcity of timberland results in upward pressures on timber prices and motivates landowners to intensify their management. Expanding pine plantations may help mitigate predicted increases in atmospheric carbon dioxide.

In the sections that follow, we examine the history, status, and possible future of southern forests and the cumulative effects of these forces of change on forest ecosystems and on expected supplies of forest goods, services, and values. We evaluate these changes in four different dimensions: social and economic systems, forest area and conditions, terrestrial ecosystems, and water and aquatic ecosystems.

3 Conditions of Southern Forests

The South has a strong regional identity that belies its broad ecological and cultural diversity. Its landscape is a patchwork of land uses and forest conditions. Social and ecological systems do not develop in isolation, and the use of land and ecosystems has had a longstanding influence on economic systems as well as on other aspects of life and livelihood in the South. The region's

diversity and complexity of landscape, economics, and culture also preclude general statements and prescriptions regarding southern forests.

The South has been a heavily worked landscape. Its forests are, almost without exception, the result of multiple disturbances and land use changes. Nearly every forested acre in the South has been harvested at least once in the last two centuries. Prior to European settlement, Native Americans modified the composition and structure of forests with fire and crop cultivation. Following European settlement, three historical epochs in land use and resource extraction both shaped the region's landscape and influenced its cultural history. They provide lessons regarding exploitation, management, and renewal.

Agricultural exploitation on a landscape scale began in the 17th century but reached its zenith in the late 19th century as a vast cotton industry stretched from the Atlantic to Texas. Other crops supplanted cotton as the boll weevil ran its course, and all have had influences on the land. A second epoch involving widespread timber exploitation in the first part of the 20th century had its roots in the disposal of a large public domain in the years immediately after the Civil War. The timber industry migrated to the South after timber stocks were depleted in the Lake States. Some 20 years of extensive logging heavily depleted southern timber stocks. By the beginning of the Great Depression much of the region was forest-resource poor and its soil greatly degraded. Wholesale land abandonment followed and set the stage for the third epoch, a 40-year period of regrowth of southern forests.

Current conditions and opportunities reflect this history of use. For example, much of natural-pine area originated from the seeding of abandoned agricultural fields. Settlement and agricultural development permanently displaced various wildlife species and led to extinctions. Current sediment loads in many streams are largely the result of agricultural activities and logging in the 19th century. These sediment loads continue to influence aquatic ecosystems.

The South is now a heavily forested region. Forests cover more than 60 percent of most States. Agriculture dominates on the upper Atlantic Coastal Plain, the Mississippi Alluvial Valley, the Interior Plateau, and the Ridge and Valley regions of Tennessee and Virginia. Elsewhere, forests cover an even greater share of the landscape.

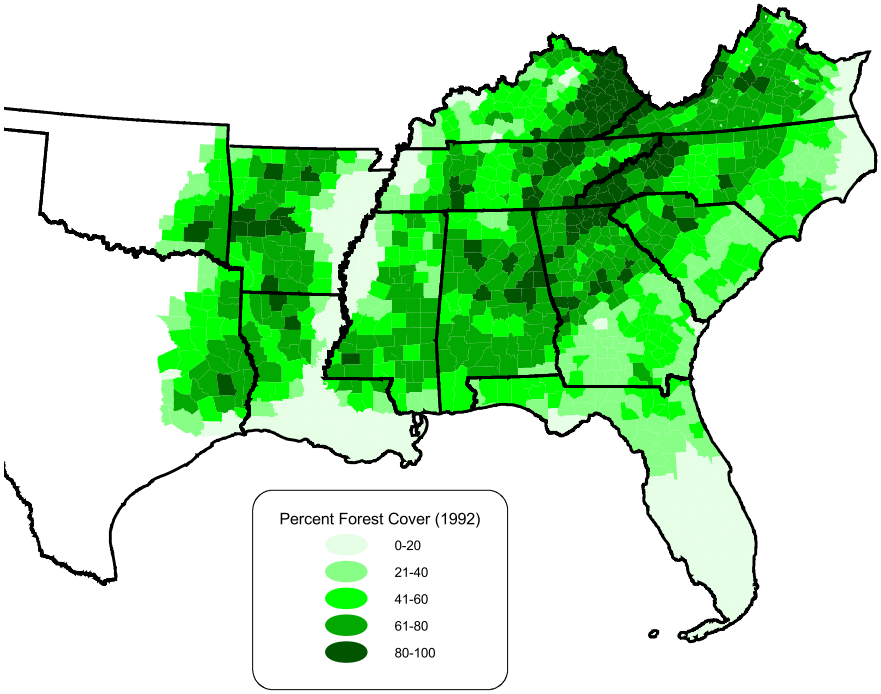

Figure 3.1—Percent of forest cover by county, 1992. Source: SOCIO-1, Figure 17.

The broad ranges of ecological conditions that comprise the region demonstrate that its forests are diverse (Figure 3.2). Their productivity and sensitivity to change vary greatly, reflecting continued reshaping in response to several modern forces of change. The following sections evaluate the potential implications of these changes.

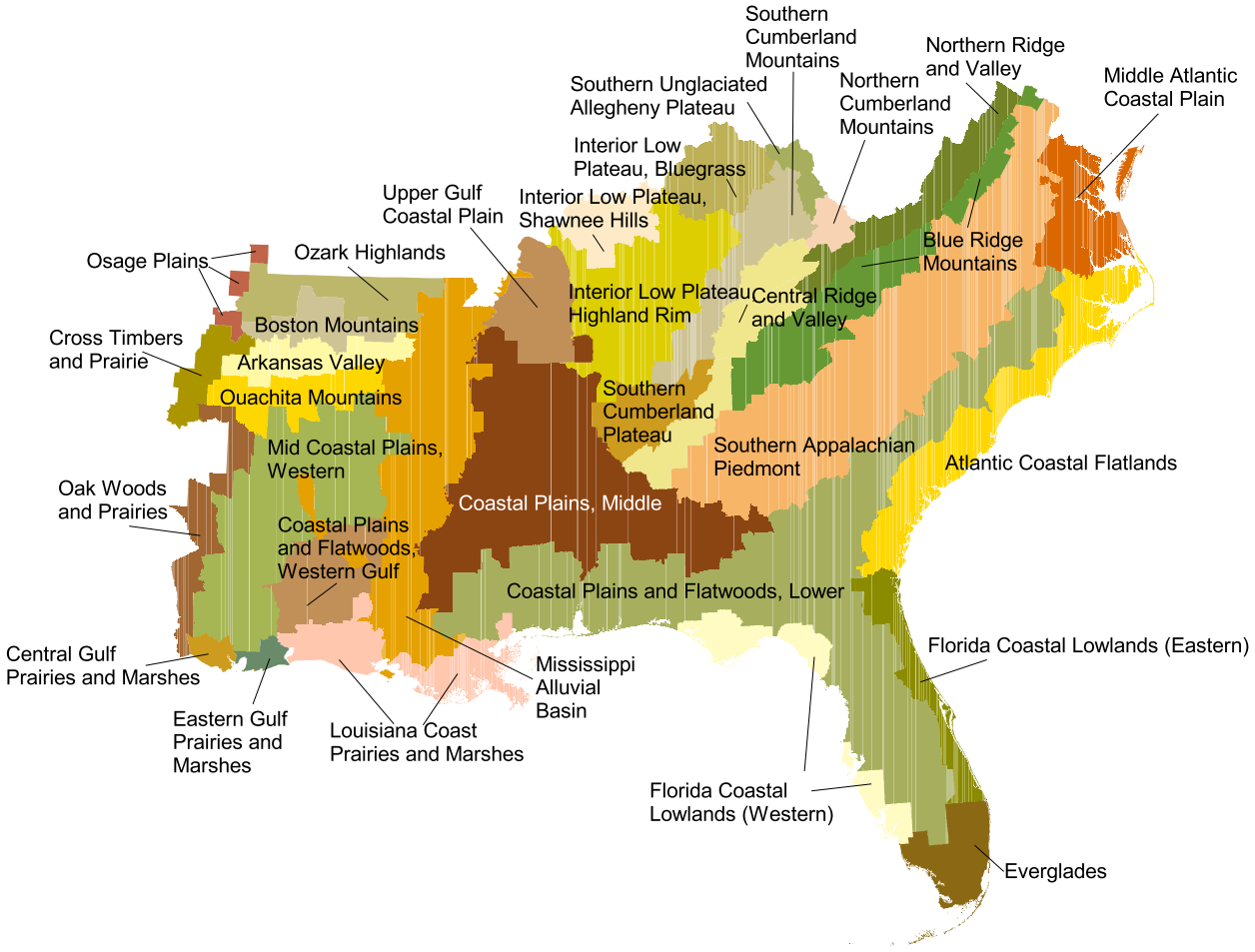

Figure 3.2—Ecological sections of the South.

3.1 Social and Economic Systems

Uses of land and forests are linked to the economic structure of the region. Benefits flow from the region's forests in several forms. Timber harvests provide the largest flow of cash revenue from forests, but other benefits are also substantial. Recreational uses of forests are highly valued, including the direct consumption of recreational experiences and aesthetic and spiritual values that people place on nature. Forests protect soil integrity and water quality and provide terrestrial habitats for much of the region's flora and fauna. Thus, forests are vital in many ways.

In this section we examine the South's growing population and changing demographic profile. We then examine the two direct sources of commodity benefits flowing from southern forests—timber products and recreation. We conclude with a discussion of the broader influence of forests on quality of life and the implications of anticipated changes on these functions. Throughout, we focus both on how human activities influence forests and how benefits are derived from forests.

3.1.1 Social Context

Primary Question:	SOCIO-2: What are the attitudes and values of southern residents toward forests and their management and how have they changed over time and do they differ by demographic groups?
Related Questions:	SOCIO-4: What motivates private forest landowners to manage their forest land and how are their management objectives formed?

The population of the United States roughly doubled between the late 1950's and 2000, and the population of the South has grown at an even faster rate (Figure 3.1.1). The South's population grew by 13.7 percent between 1990 and 2000, and the share of the U.S. population living in the South grew from 30.7 percent in 1990 to 32.5 percent in 2000. Much of this growth has been focused in urban areas such as Atlanta and Miami and along the eastern coastline. The population of the 13 Southern States stood at 91,486,129 people on April 1, 2000.

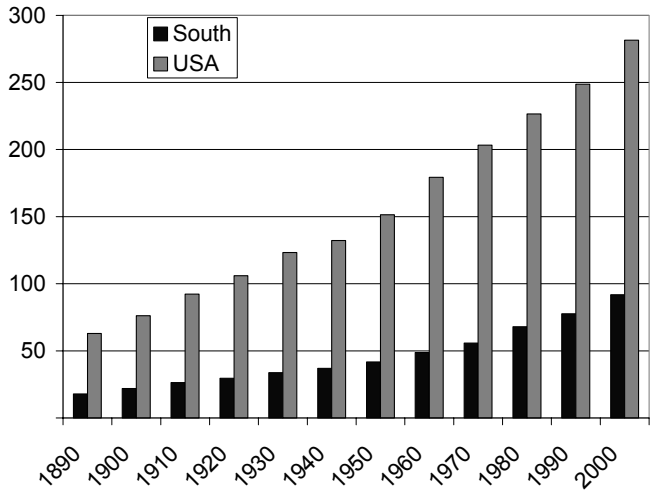

Figure 3.1.1—Population, in millions, for the United States and for the 13 States in the Assessment area. Source: SOCIO-1, Figure 8.

Historical data show that population contracted in rural areas and expanded in urban counties from the 1950's to the 1980's, but growth was spread across nearly every county in the region between 1990 and 2000 (Figure 3.1.2). As a result, even the population density near rural forests has expanded and will likely expand in the future. The very few areas experiencing depopulation between 1990 and 2000 were in the most rural areas of the South.

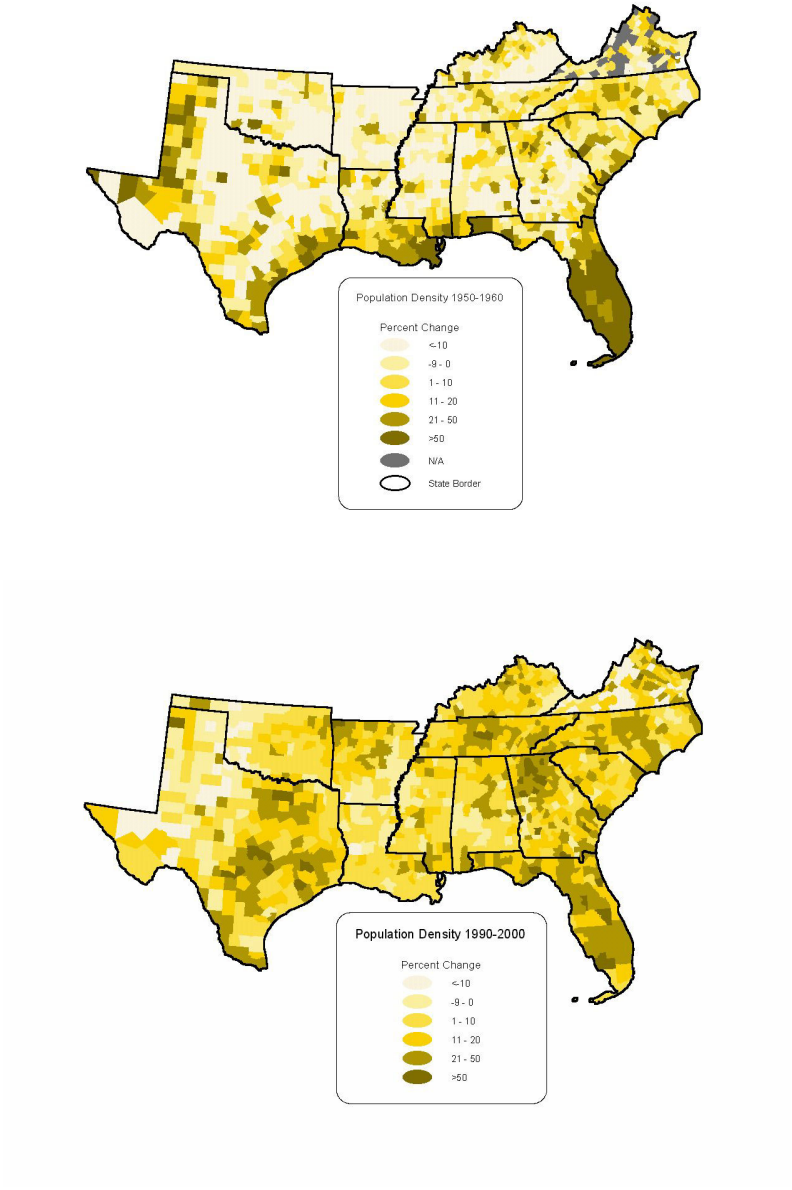

Figure 3.1.2—Percent changes in the density of population for (a) 1950-1960, and(b) 1990-2000. Source: SOCIO-1, Figure 9

Along with economic growth have come changes in the various attributes of the region's population. The population has continued to increase in racial and ethnic diversity (Figure 3.1.3). Mean incomes have increased since the 1980's but much of these gains have been concentrated in the urban areas, primarily in the eastern half of the region (Figure 3.1.4). Increases in education levels followed the same spatial patterns. Poverty rates have fallen in the recent past and are approaching U.S. averages (Figure 3.1.5).

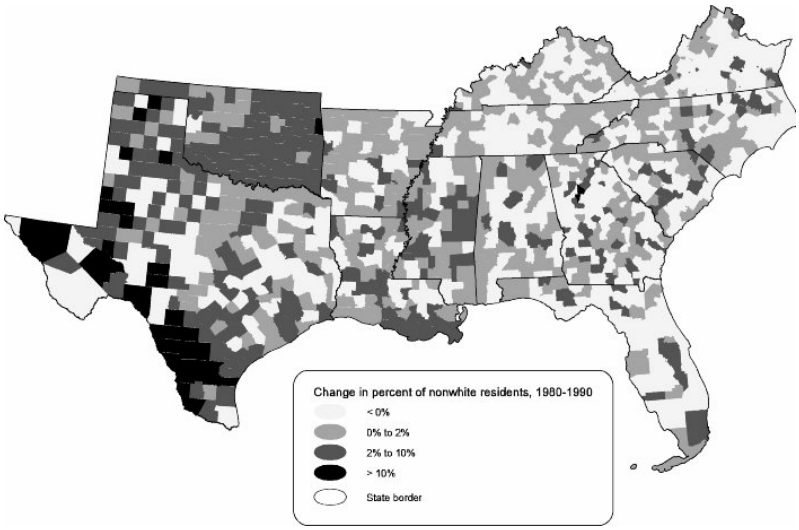

Figure 3.1.3—Change in percent nonwhite residents 1990-1999. Source: SOCIO-2, Figure 19.

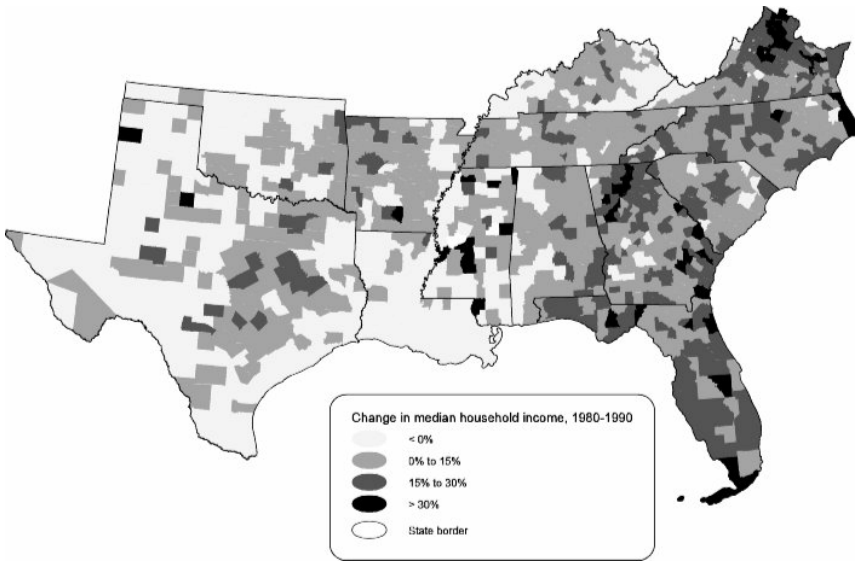

Figure 3.1.4—Change in median household income, 1980-1990 (adjusted by the Consumer Price Index). Source: SOCIO-2, Figure 21.

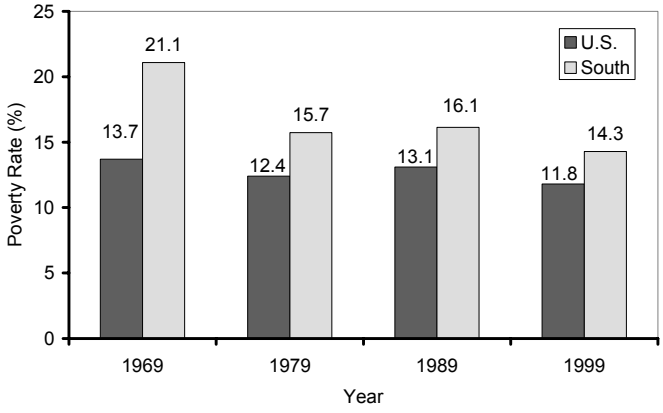

Figure 3.1.5—Poverty rate in the US and South, 1969 to 1999. Source: SOCIO-5, Figure 4.

The population has become older in many parts of the region. Compared to the national median age of 32.8 years, Florida's is 42. The population is expected to age in all States, changing the demand for various services, but the increase in median age will be especially large in retirement destinations such as Florida and the Southern Appalachians. These changes portend changes in the demands placed by resident populations on forests for aesthetic and recreational uses.

Upward trends in population along with change in other demographic variables reflect changes in the way southerners view and use forests (SOCIO-2). Especially in the urbanizing areas of the South, there is an unambiguous trend toward increasing scarcity of certain forest services in urban areas as populations increase rapidly coincident with a decline in the area of forests (especially large contiguous forests). Perhaps reflecting this increasing scarcity, public values about forests and their management have changed over the past two decades. Survey-based studies show values have shifted from a largely commodity-oriented, anthropocentric perspective on forest management toward inclusion of natural biological factors in a biocentric approach (SOCIO-2). Southern residents generally favor additional funding of environmental protection. Perhaps surprisingly, we found little significant differences between the attitudes and values held by rural and urban residents. However, young people had more biocentric views than older people, placing more value on scenic beauty and less on wood production (SOCIO-2).

Surveys of forest owners (SOCIO-4) and the public in general (SOCIO-2) indicate that "conservation" ranks high as a value with both sets of people and recent changes in attitudes reflect a growing concern for environmental quality in addition to the commodity benefits that flow from forests. It is clear that forests play both direct and indirect roles in determining quality of life in the South.

3.1.2 People and Forests

Primary Question:	SOCIO-1: How have land uses changed in the South and how might changes in the future affect the area of forests?
Related Questions:	TERRA-1: What are the history, status and projected future of terrestrial wildlife habitat types and species in the South?

Conversion of forests to developed uses is associated with population growth. Substantial population and income growth is forecast for about a third of the region's counties. Urbanization will be concentrated in three large areas: the Southern Appalachian Piedmont stretching from Raleigh/Durham through Atlanta; the Atlantic Coast from the Carolinas through Florida, and a portion of the gulf coast centered on Mobile Bay. Other centers of expanding urbanization are around Nashville and Knoxville and in northern and eastern Virginia (Figure 3.1.6).

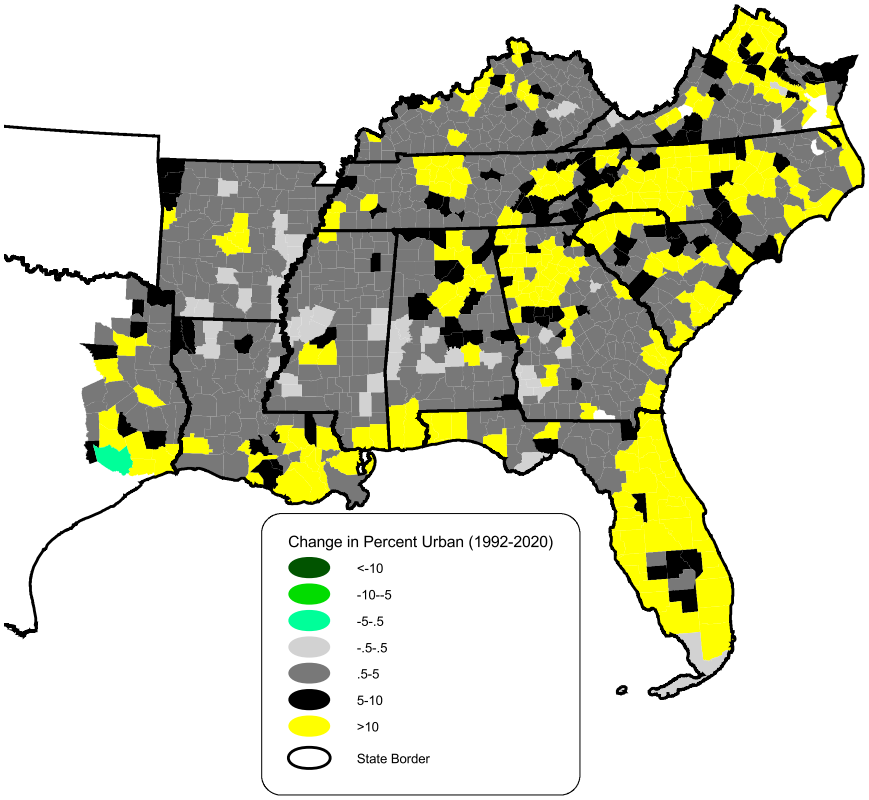

Figure 3.1.6—Forecast change in the share of land that is urban for counties in the South 1992 to 2020. Source: SOCIO-1, Figure 13.

Many developed areas of the South still retain much forest cover. However, these forests are becoming fragmented, suggesting that they do not have the potential to provide the same ecological

and economic values as forests in a rural setting. One way to gauge fragmentation is to examine the share of land in interior or unfragmented forest (that is a forest area that is completely surrounded by other forest areas). A measure of forest cover developed from satellite imagery shows that interior forest is especially scarce in the developing areas mentioned above (Figure 3.1.7, SOCIO-1).

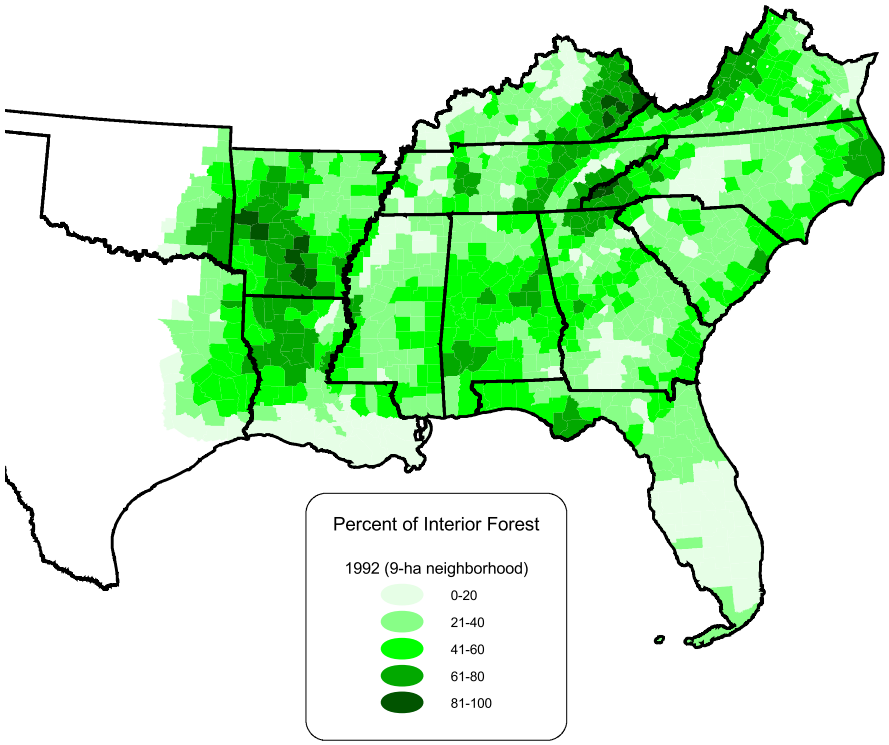

Figure 3.1.7—Percent of interior forest by county, 1992. Source: SOCIO-1, Figure 17.

The influence of urban areas on forests extends outward into surrounding rural areas. Areas influenced by urban development will likely experience growing human populations and changes in the values and uses of forests. For example, forest services such as recreation and microclimate moderation may become more highly valued in an urbanizing area. Timber management, on the other hand, is generally inversely correlated with population density. Timber harvesting near urban areas will likely decrease substantially after the harvests associated with land clearing and conversions (SOCIO-1).

One measure of human presence in the vicinity of forests is “forest population density” (FPD), which is the number of people per square mile (ppsm) of forest within a county. The index ranges from about 20 ppsm in very rural areas of the South to more than 1,000 in urbanized areas (we

consider 1,000 ppsm a "saturated" condition). Figure 3.1.8 shows that, as expected, FPD is highest in the vicinity of large cities. Florida has the highest concentration of these saturated areas, reflecting a very high population density through much of its peninsula and low forest cover in the southern half of the State. Three other areas along interstate highway corridors had high FPD values in 1992: the I-85 corridor from Raleigh/Durham to Atlanta, the I-65 corridor from Birmingham to Nashville, and the I-81 corridor from Chattanooga to Wytheville, VA. At the periphery of the region in northern Kentucky and Virginia and along the gulf coast, FPD's were also relatively high in 1992.

Forecasts of changes in FPD's from 1992 to 2020 indicate continued outward growth of the urban centers of the South. Figure 3.1.9 shows a characteristic "doughnut" pattern of growth in FPD around Atlanta, Nashville, and Charlotte. Expansion in FPD is also forecast to be concentrated in Atlantic Coastal areas of South Carolina and Florida, and along the Gulf coast. A similar pattern is also evident around the concentration of public land in the Southern Appalachians.

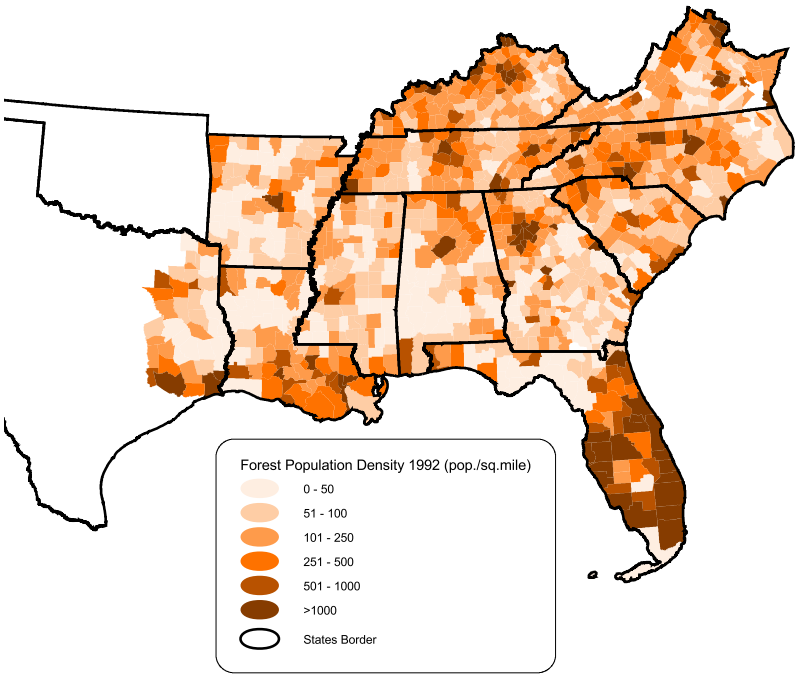

Figure 3.1.8—Forest Population Density Index (FPD) in people per square mile (ppsm) of forest by county for 1992. Source: SOCIO-1, Figure 15.

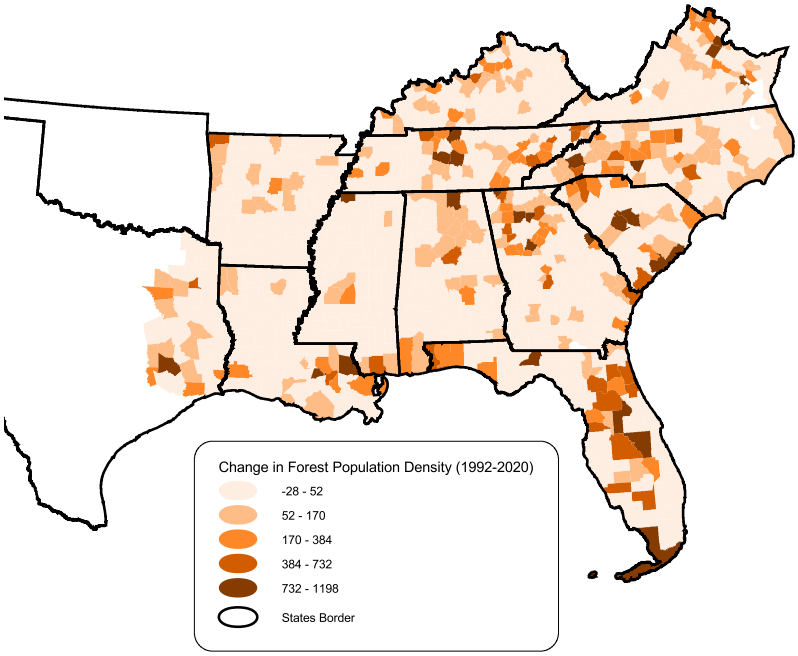

Figure 3.1.9—Change in Forest Population Density for 1992-2020. Source: SOCIO-1, Figure 15

3.1.3 Wood Products

Primary Question:	TIMBR-1: What are the history, status and projected future demands for and supplies of wood products in the South?
Related Questions:	TIMBR-2: What are the status and trends of forest management practices in the South?
	TIMBR-3: How might existing and new technologies influence forest operations and resultant conditions of forests?

Timber harvesting and wood products manufacture yield the largest direct revenue from forests in the South. Timber produces a large share of land-based revenues in rural areas and influences forest conditions. Timber harvesting changes the structure of forests, but strong timber markets have also encouraged landowners to keep land in forest cover, to convert agricultural land to forest uses, and to otherwise invest in silvicultural activities.

Since the 1960's, the consumption of wood products has steadily expanded in the United States, and timber production from western U.S. regions has declined. As a result, the South now produces nearly 60 percent of the Nation's wood output since the 1990's. The South produces a highly

diverse complement of forest products. Both hardwoods and softwoods are used for lumber, plywood, composite boards, poles, paper, and other products (TIMBR-1).

Timber harvesting and management for timber production are prevalent in all parts of the region, but especially on the Atlantic Coastal Plain from South Carolina to northern Florida and the Gulf of Mexico Coastal Plain from northern Florida to eastern Texas. Recent developments in the wood products industries have resulted in a shift outward from the Coastal Plain to more western and northern parts of the region. These shifts are explained by overall increases in wood products demand but also by changes in wood products technologies, which allow for the utilization of lower quality and smaller sized timber, particularly hardwood timber (Section 2.3).

Across the South, wood products industries have provided large shares of employment and income. In 1997, the most recent year for which complete data are available, timber harvests led to more than 700,000 jobs in the wood products sector and yielded more than $118 billion in total industry output. The total impacts of activities in the wood products sector were about 2.2 million jobs and $251 billion of total industry output in 1997 (this includes indirect and induced jobs and income). These totals represent 5.5 percent of jobs and 7.5 percent of total industry output in the South (SOCIO-5). In addition:

- Forests are important in the local and regional economies of the South. The overall southern economy has grown since 1969, with total jobs increasing consistent with increases in population in the national economy. This new economy is less dominated by manufacturing and agriculture. Timber and agriculture, the two major uses of rural southern land still contribute over 6 percent to the southern economy.

- The U.S. wood products industry continues to concentrate in the South, which had 39.3 percent of U.S. wood products jobs in 1997. The percentage of State-level jobs and income in wood products declined between 1969 and 1997, yet actual numbers have remained fairly constant.

Forecasts indicate continued expansion in timber harvests between 1995 and 2040. Increased demands for southern wood products will influence not only the amount of timber harvested but also the location of harvesting. We examined forecasts of timber harvesting and found (TIMBR-1):

- Softwood and hardwood harvests are forecast to increase by 56 and 47 percent respectively between 1995 and 2040.

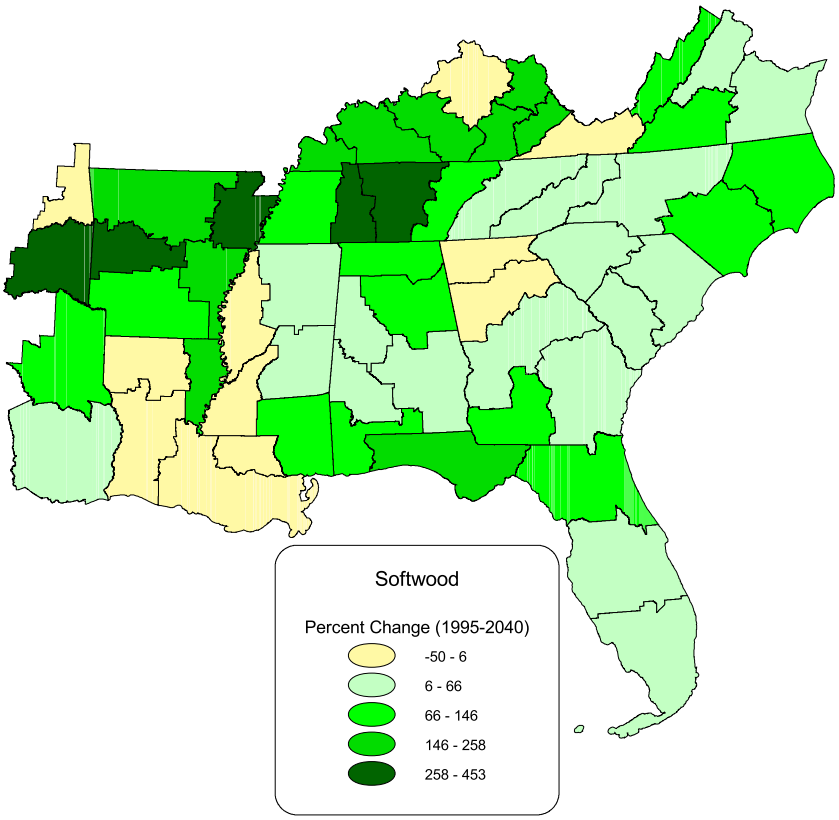

Figure 3.1.10. Forecast percent change in annual softwood harvest levels, 1995-2040, by survey unit of the Forest Inventory and Analysis Program of the USDA Forest Service. Source: TIMBR-1, Figure 28a.

- Production of softwoods is currently concentrated on the Coastal Plain and, to a somewhat lesser extent, on the Piedmont. Softwood production in this core area is forecast to increase somewhat over the next 50 years. Softwood production is also forecast to increase to the north and west of this core area, in central and western Tennessee, northern Arkansas, Kentucky, and western Virginia. In these areas, softwood harvests are forecasted to increase by more than 25 percent (Figure 3.1.10).

- Declines in softwood harvests are forecast for northern Georgia and for an area that includes portions of Louisiana, eastern Texas, and northern Mississippi.

- While regional softwood harvests are forecast to increase substantially, the volume of softwood inventory would also increase over the next 50 years. Strong and relatively stable markets for wood products would encourage landowners to continue to invest in growing timber. As a result, the area of pine plantations in the South is forecast to increase by more than 60 percent between 1995 and 2040 to 54 million acres. These pine plantations are forecast to be managed for short rotation timber production.

- Four States—Georgia, Alabama, Florida, and Mississippi—currently contain and are forecast to contain more than 50 percent of the area of pine plantations (Figure 3.1.11).

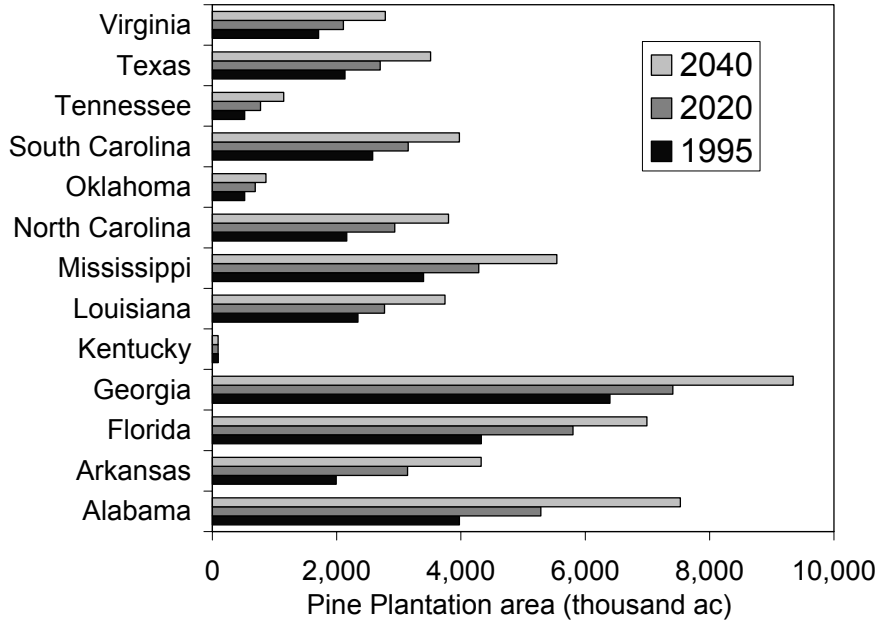

Figure 3.1.11—Pine plantation area by State for 1995, 2020, and 2040. Source: TIMBR-1, Figure 21.

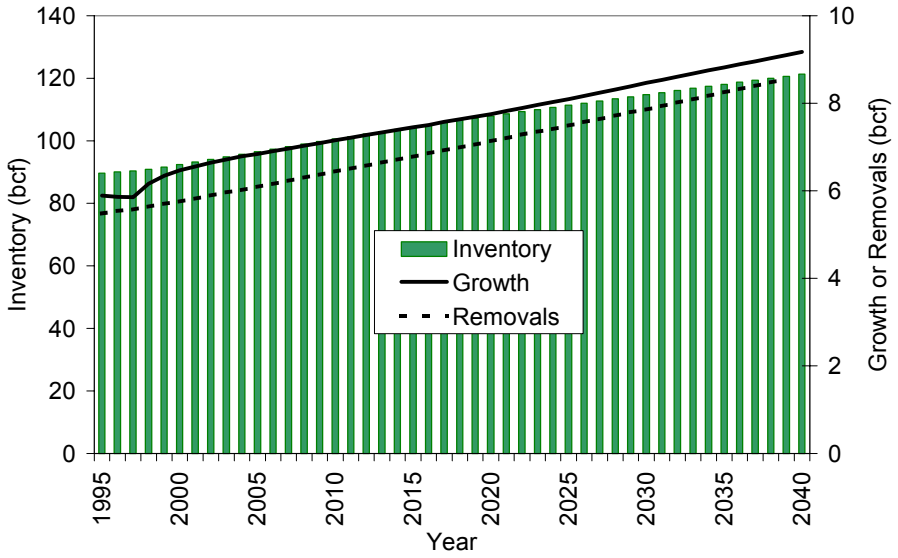

Figure 3.1.12—Forecasts of softwood timber growth and removals volumes, in billion cubic feet (bcf), 1995-2040. Source: TIMBR-1, Figure 24.

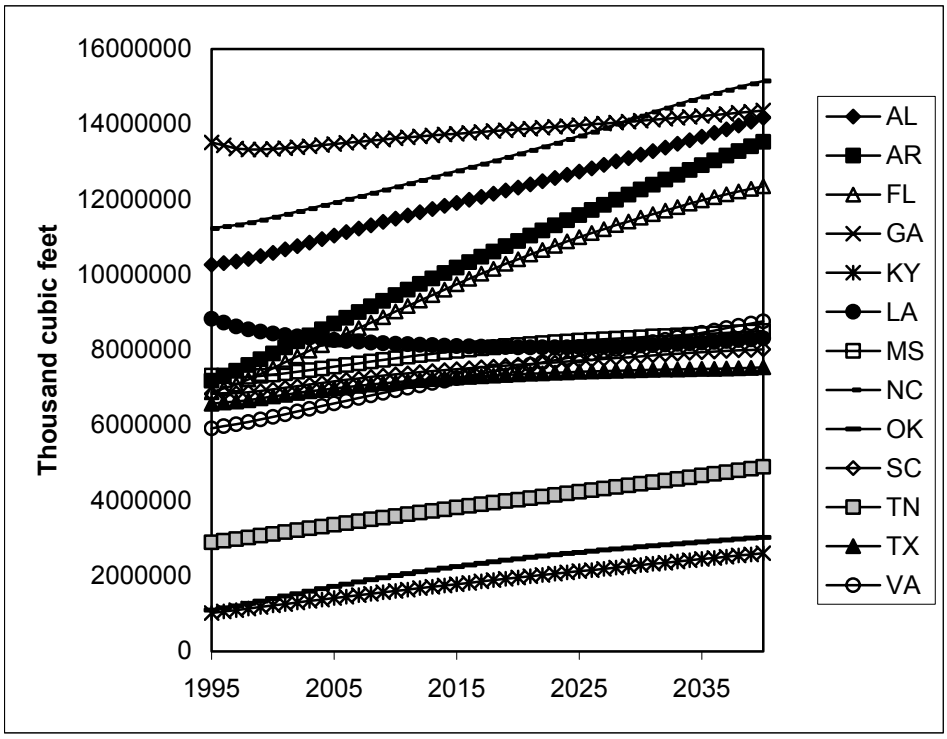

Figure 3.1.13—Softwood inventory by State, 1995 to 2040. Source: TIMBR-1.

- Forecast changes in softwood inventories vary by State. Alabama, Arkansas, Florida, and North Carolina are forecast to experience large increases in softwood inventories (Figure 3.1.13). Louisiana is forecast to be the only State with a decline in softwood inventory (decline of 6 percent between 1995 and 2040). All other Southern States are forecast to experience at least a small increase in softwood inventories, indicating that net growth exceeds removals throughout the forecast period.

- Hardwood harvests are forecast to increase the most in regions with large hardwood inventories. Expanding hardwood harvests would be concentrated in a large contiguous area stretching from northern Alabama and Georgia to the northern boundary of the Assessment area. This area includes all of Kentucky, the central and western portions of Tennessee, western North Carolina, and northern and western Virginia. Harvests are also forecast to expand in northern Arkansas (Figure 3.1.14).

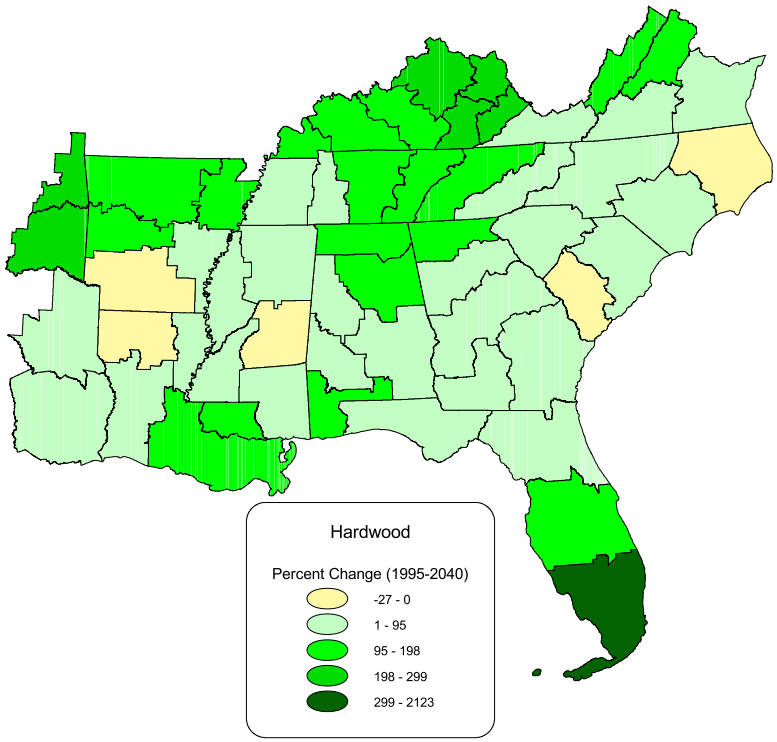

Figure 3.1.14—Forecast percent change in annual hardwood harvest levels, 1995 to 2040, by survey unit of the Forest Inventory and Analysis Program of the USDA Forest Service. Source: TIMBR-1, Figure 33a. Note the large percentage change in southern Florida is due to a very small base harvest in 1995.

- With hardwoods, the rate of removals is forecast to gradually approach the rate of growth between 2020 and 2025. As a result, hardwood inventory is forecast to peak in 2025 and then to decline between 2025 and 2040. Inventory in 2040 is still forecast to be somewhat higher than current inventory (Figure 3.1.15). Forecasts of hardwood inventories vary by State. Kentucky, Oklahoma, and Tennessee show increases throughout the forecast period indicating that net growth exceeds removals throughout the period. Mississippi and South Carolina show inventories declining for nearly the entire forecast period, indicating that removals exceed net growth from the late 1990's forward. Georgia, Texas, and North Carolina have hardwood inventories peaking between 2007 and 2018, and then begin to decline. The remaining States are forecast to accumulate volume until sometime between 2021 and 2031, at which point removals begin to exceed net growth and hardwood inventories begin to decline (Figure 3.1.16).

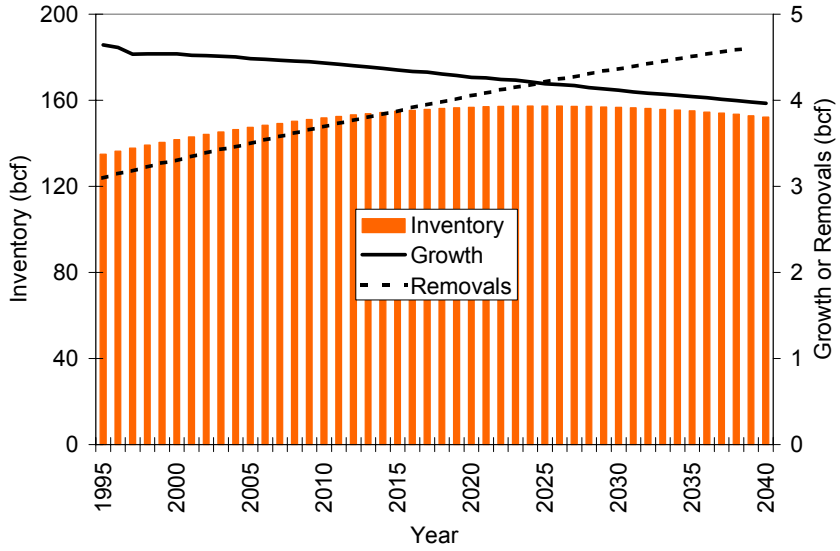

Figure 3.1.15—Forecasts of hardwood timber growth and removals volumes (bcf), 1995-2040. Source: TIMBR-1, Figure 29.

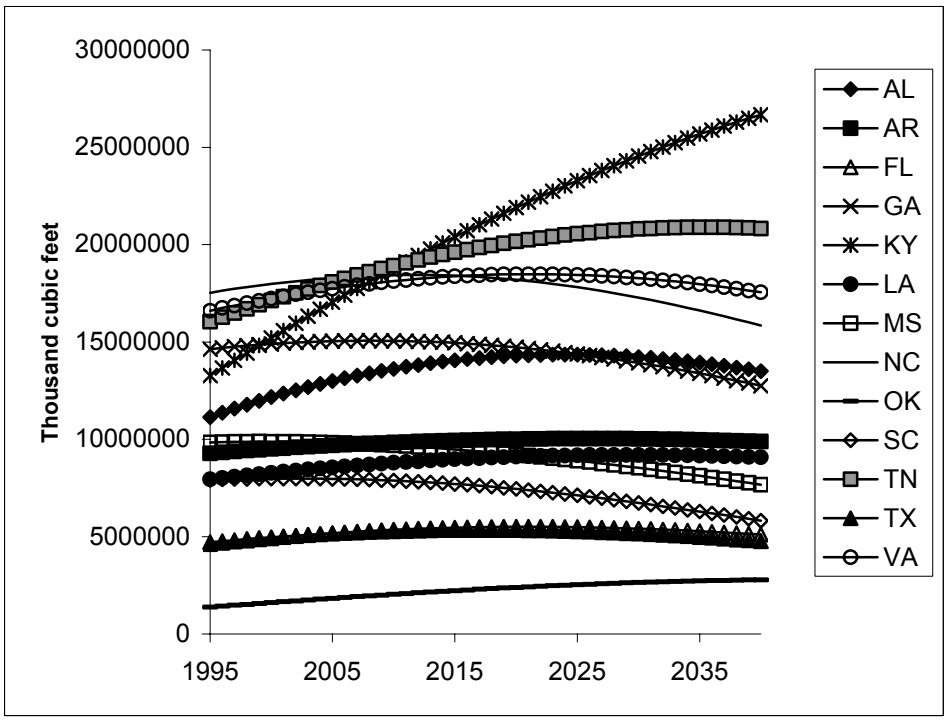

Figure 3.1.16—Hardwood inventory by State, 1995-2040. Source: TIMBR-1, various figures.

- Real prices for hardwood and softwood products (i.e., after accounting for inflation) are forecast to increase between 2000 and 2040. While investment in softwood forests has been a demonstrated response to increasing softwood prices, major investments in hardwood production have not yet occurred in the South. However, the feasibility of short-rotation hardwood management has been demonstrated and could conceivably reduce these price increases and reverse inventory declines.

3.1.4 Recreation

Primary Question:	SOCIO-6: What are the supplies of and demands for forest based recreation and other noncommodity uses of forests in the South?
Related Questions:	SOCIO-5: What role do forests play in employment and local economies in the South?

Southern forests are the settings for a wide variety of recreation activities. We examined recreation use, the influence of population growth and change on recreation demand, and changes in recreation supply (SOCIO-6).

Driven by a growing population and changes in demographic characteristics such as income and median age, participation in outdoor recreation of all types has increased in the South. Some activities, including viewing and photographing nature, gathering various forest products, and certain forms of boating have grown more rapidly than others. The most popular outdoor recreation activities among southerners tend to be the least expensive and include walking for pleasure, attending family gatherings, picnicking, and visiting historic sites. Next in popularity are activities such as viewing and photographing wildlife, fishing, gathering forest products, hiking, hunting, and biking, which require somewhat more financial outlay. In general, the popularity of the activity is inversely related to the cost of participation. Among the various classes of recreational activities, those focused on viewing, learning, and photographing in natural areas have been expanding the most rapidly (SOCIO-6).

The patterns of recreation participation among southerners are very similar to averages for the United States as a whole. However, with the exception of water-based activities, the level of participation in the South is lower.

In addition to the growth in largely nonconsumptive recreation activities, recreation focused on the harvest of various nontimber products has also grown. A recent survey showed that 31 percent of respondents in the South participated in some form of this activity. Products included firewood, rocks and minerals, berries, mushrooms, herbs, flowers and other decorative plant materials, and

several other minor products (SOCIO-6). A small percentage of people (2 percent) indicated that they collected forest products for income; 96 percent collected for personal uses. Fifty-four percent collected in a forest setting. Based on the income distribution of respondents who participated, it appears that only a small portion engaged in gathering as a subsistence activity (SOCIO-6).

Recreation and tourism, including that derived from forested settings, is a source of employment and income in the South.

- In 1997 outdoor recreation-based tourism contributed between 0.64 and 2.88 percent of southern jobs and between 0.51 and 2.51 percent of the South's gross regional product. Public lands represented 56 percent of this contribution (SOCIO-5).

- Tourism-related industries are increasing in the South but are not becoming more concentrated. The percentage of State-level jobs and income in the tourism-related sectors has increased in all 13 States, as have the actual numbers of jobs and amount of income (SOCIO-5).

Forest-based recreation is largely concentrated on relatively scarce public land. Because only 4.6 percent of Federal land and 12 percent of State park and forest lands are in the South, which has about 33 percent of the Nation's population, recreation pressures on public land are substantial. For example, U.S. national forests in the Southern Region are the second most heavily used of the nine USDA Forest Service regions with visits of 1.9 per acre (SOCIO-5). Only 7 percent of private land held by individuals is open to free access by any member of the public and the trend is toward decreasing access to private land (SOCIO-6).

Increased demand for outdoor recreation will therefore likely be placed on public lands. The ability to provide these kinds of uses will be constrained by Federal budgets and by the mandates of the various Federal agencies. For example, national parks are managed with a mandate to protect natural, historic, and cultural areas, and management of wildlife refuges must focus first on wildlife conservation.

- Given the current land ownership patterns and owner objectives, there appears to be limited capacity to expand forest-based recreation opportunities in the South. There is a trend toward increasing scarcity of recreational opportunities (SOCIO-6)

Recreation areas on public land will likely be increasingly congested, and competition between various recreation user groups for limited area is forecast to increase based on forecast population growth. Competition may be greatest between nature viewing activities such as bird watching and nature photography, and technology-based activities, such as mountain biking and other forms of mechanical trail use.

- As recreation congestion increases, the costs imposed on owners of private tracts may increase. This could lead to more restricted uses of private land thereby shrinking supply and increasing congestion even further.

- Furthermore, competition between recreation types indicates that investment to support one type of recreation activity may diminish opportunities for other types. Because public land is so scarce, tradeoffs between recreation opportunities are critical issues for forest managers.

Another important outcome of recreation congestion is the potential for damage to the productive and protective capacity of forest ecosystems. Recreation can damage soils through compaction, pollute water, damage and alter vegetative cover, and influence native wildlife populations. While a complete assessment of existing or potential damage has not been conducted, increased damages are expected in the "recreation hot spots" identified in Figure 3.1.17. In these areas, heavy recreation pressures on forest resources are anticipated (SOCIO-6).

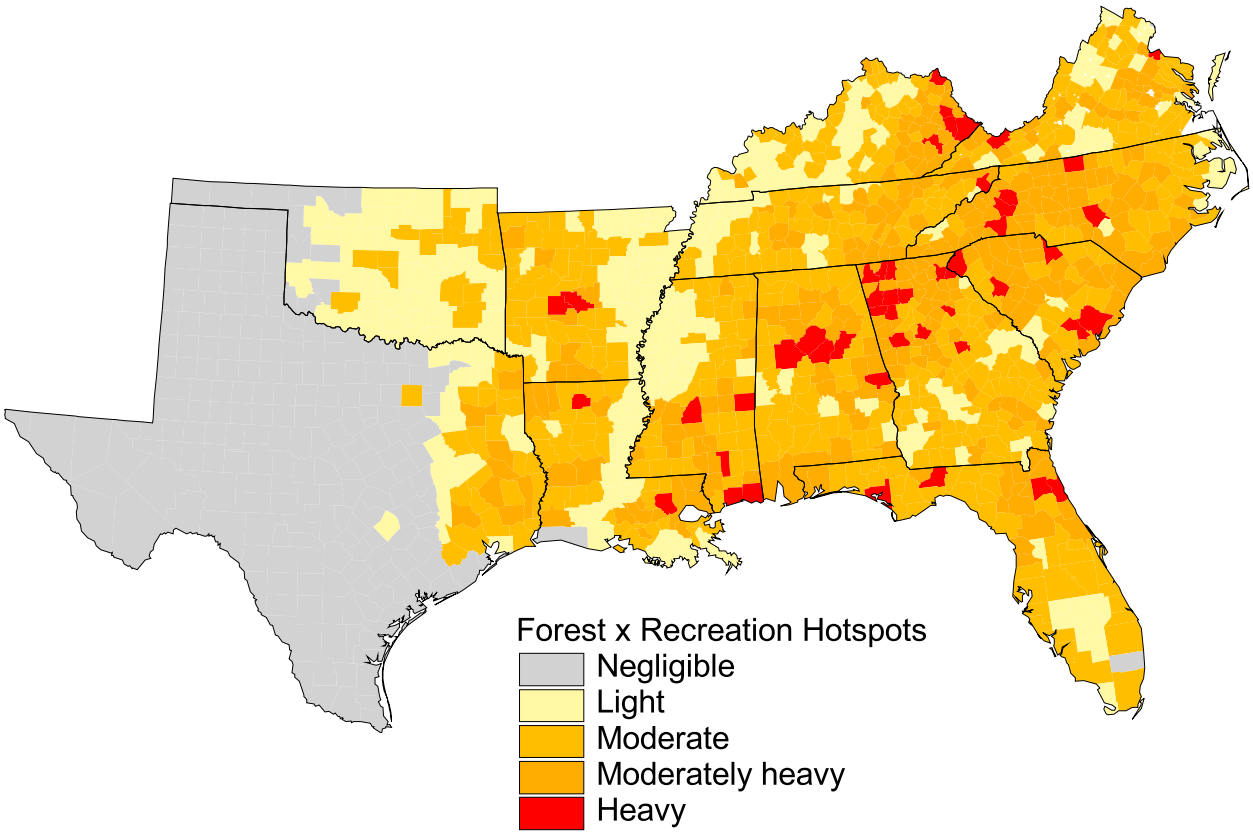

Figure 3.1.17—Hotspots of recreation demand pressure on forests, 2000. Source: SOCIO-6, Figure 1.

Increasing recreation participation rates combined with population growth and decreased forest area adjacent to urban areas portend substantial challenges for public forest managers. These include addressing user competition and mitigating recreation-related environmental damages.

3.1.5 Quality of Life

Primary Question:	SOCIO-7: How do forests and their uses influence the quality of life in the South?
Related Questions:	SOCIO-5: What role do forests play in employment and local economies in the South?

Quality of life depends on a multitude of factors. These factors can be placed in three categories: (1) economic well-being, (2) social well-being, and (3) environmental quality. Land use and forest conditions can have a bearing on the quality of life in local areas (SOCIO-7).

Economic well-being is generally defined as the production of wealth, which allows for the purchase of goods and services. Forests produce wealth in several ways. Timber harvests generate income and a return to investments in land and forest management. Employment and returns to capital accrue as primary wood manufacturers convert raw timber products into intermediate products such as pulp, paper, and lumber. Secondary wood products industries such as furniture manufacturing, which utilize these intermediate products, also generate employment, income, and returns to capital investments. Additionally, forests provide settings for outdoor recreation that can produce wealth for local areas.

The production of wealth is important, but it provides an incomplete assessment of the contribution of forests to the quality of life in a region. Another element is social well-being, which is generally measured in terms of the social conditions and services found in a region. Examples include crime, education, and access to health services. Forest cover and even uses do not cause these conditions. However, correlations between these conditions and social indicators can provide insights into the social context of places influenced by forest uses. A comparison of social and economic conditions with the share of wood products and recreation and tourism employment found:

- The forest products industry was located in areas where economic opportunities and diversity were limited.
- The forest products industry provided good paying jobs in areas where other economic opportunities were limited. On average, wages in this industry ranged from marginally higher (in the primary and secondary wood products sectors) to much higher than “typical” wages (that is, average wages in nonforest product industrial sectors).
- Through export of wood products to other regions, the forest products industry contributed to local economies by bringing in income which then circulated through economies via the purchase of locally provided goods and services. In areas where employment in the wood products industry comprised at least 10 percent of local employment, the industry contributed more than half of the jobs in the economic base.
- Concentrations of employment in the forest related recreation and tourism sector were

associated with better economic conditions in rural areas of the South—that is, was correlated with an increase in median household income and with a decline in unemployment and poverty rates.

Another element of quality of life is environmental quality, or the set of services derived from local settings. Several nonmarket benefits are associated with forests and forest uses, such as high quality water and natural settings. Precise measurement of the value of nonmarket benefits is very difficult, but a valuation of these benefits is reflected in the willingness of some rural residents to live in a particular locale irrespective of wages. Environmental quality appears to play an especially important role in selection of a residence by retirees. We examined the conditions of forests in counties that depend on primary wood products and found (SOCIO-7):

- Forests in areas with high concentrations of wood products manufacturing show greater influence of management. They have higher concentrations of plantation acreage, younger pine forests (high pine growth relative to standing inventory), and greater timber harvest intensity in hardwood forest (greater removals relative to standing inventory).

Nonmarket benefits associated with "naturalness of forests" may, therefore, be lower in areas dominated by the wood products industries, while marketed benefits and employment and income associated with wood products are higher as described above.

People choose where to live based on a bundle of attributes related to each location. These include elements of economic and social well-being and environmental amenities, as well as other variables not described here. Living in a forested rural county with little timber management activity may indeed reflect a preference for natural forest conditions. Living in urban areas or heavily managed rural areas reflects yet other preferences.

Harvesting in a new area can therefore have multiple effects on local populations. Some benefit from direct and indirect employment and income. Others may lose certain non-income benefits they derive from an unmanaged forest landscape. Thus, we would expect that the emergence of timber production in new areas would lead to debate over appropriate forest uses (see TIMBR-1 for detailed timber harvest forecasts). This factor, combined with timber harvest forecasts indicate that such debates may occur in parts of the Piedmont areas of North Carolina and in central Tennessee, Kentucky, and parts of Virginia. We see evidence of this in recent debates over chip mills in these States.

These same types of impacts on quality of life also arise because of urban development. Therefore, where development and increased timber production converge, their impacts and ensuing conflicts may be compounding. For example, places like the Piedmont would appear to be experiencing substantial change in quality of life through rapid urbanization and population growth.

3.2 Forest Area and Conditions

In this section we examine trends in forest area and conditions as measured by surveys conducted by the Forest Inventory and Analysis (FIA) Program of the USDA Forest Service. In the past these have been periodic surveys, conducted every 5-10 years. Accordingly, totals for the South are based on data from State surveys taken in different years, and current conditions are estimated from the most recent surveys. While some of the data are somewhat dated, these are the best and only comparable data available for measuring forest conditions at this level of detail and scale. New survey procedures are being implemented to provide annual updates of forest conditions, but such data were not available for this report. We also examine forecasts for some measures of forest condition.

3.2.1 Forest Area and Ownership

Primary Question:	HLTH-1: What are the history, status, and projected future of southern forests?
Related Questions:	SOCIO-4: What motivates private forest landowners to manage their forest land and how are their management objectives formed?

Based on the most recent FIA estimates, the South has more than 214 million acres of forest land. This area of forest is 60 percent of the area of what was likely present in 1630, and 91 percent of what was likely present in 1907 (Figure 3.2.1). Since the 1970's, the total area of forest land has remained relatively stable; 218 million acres were present in 1982, and 212 million acres in 1992 (HLTH-1).

Ninety-three percent of the South's forest land is classified as "timberland" by FIA. While not necessarily managed for timber products, this land has enough physical productivity to make timber production plausible. Also, timberland does not include public lands withdrawn from potential timber harvesting, such as designated wilderness areas. At 201 million acres, the area of timberland has been essentially stable since 1982 when it was 198 million acres. Many of the variables used by FIA to describe the characteristics of forests are recorded only for timberland, and detailed data on forests prior to the 1950's are generally unavailable. Accordingly, much of our description of forests is limited to the timberland portion of the South's forest area since the early 1950's.

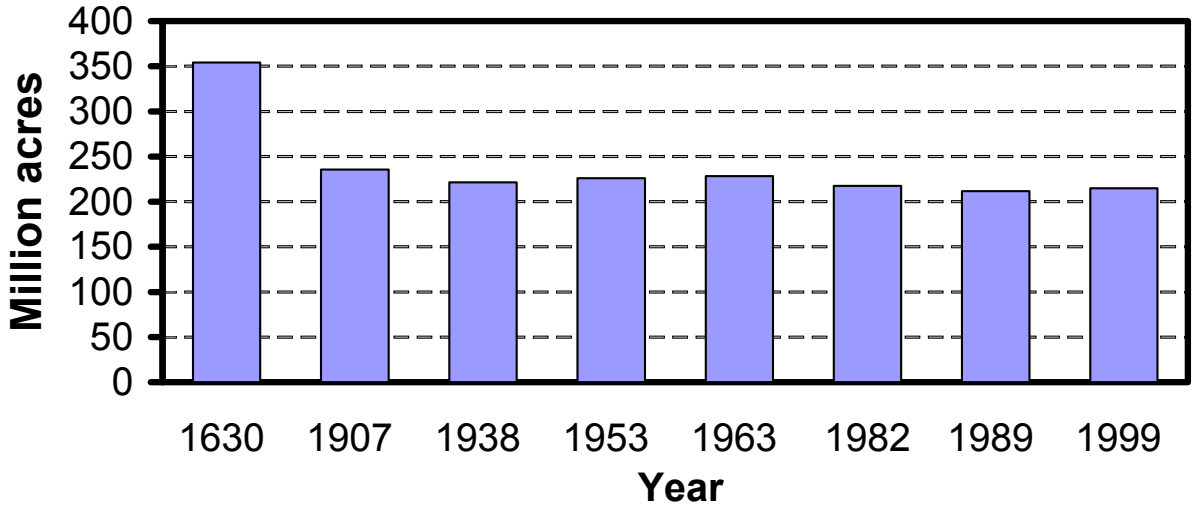

Figure 3.2.1—Forest area in the Southern United States, 1630 to 1999. Source: HLTH-1, Figure 1.

The stability in total area of timberland is the result of considerable area changing both into and out of forest cover. FIA records indicate that, over the past 20 years, as much as 2 to 3 million acres per year have experienced a change either from forest to nonforest or *vice versa*. These changes have been focused in different parts of the region, with recent losses prevailing in Florida and Louisiana and gains prevailing in Alabama, Arkansas, Mississippi and Kentucky. Between the 1950's and 1990's, Florida had by far the greatest loss of timberland (3.5 million acres or about 19 percent) while Mississippi had the greatest gain (1.7 million acres or about 10 percent). Both Florida and Louisiana have experienced continuous forest loss over the past 50 years.

Timberland is held by a diverse group of owners in the South (Figure 3.2.3). Currently, about 11 percent (21.4 million acres) is controlled by various government agencies. The USDA Forest Service manages more than half of this public timberland. The remaining 89 percent of timberland is privately owned. Based on data for all Southern States except Kentucky (Kentucky's data were not classified in this way), about 22 percent of private timberland is owned by the forest industry, 21 percent by farmers, 12 percent by other corporations, and 45 percent by other individuals.

Ownership distribution is dynamic (Figure 3.2.2). For example, the area of timberland owned by forest industry declined by about 1 million acres between the 1980's and 1990's. However, this decline was more than offset by a 4.1 million acre increase in ownership by other corporations. Many of these corporate owners—including Timber Investment Management Organizations or TIMO's—practice a forest management style similar to forest industry so that the net environmental and timber supply implications of a shift from forest industry to TIMO ownership may be minimal (TIMBR-2). Forest industry's holdings also shifted westward during this period, with substantial reductions in Florida (681,000 acres) and Georgia (583,000 acres) accompanied

by increases in Alabama (591,000 acres), Arkansas (240,000 acres), and Mississippi (209,000 acres). In the 1990's, some of the highest concentrations of industrial ownership were still in the Coastal Plain of Georgia and northern Florida.

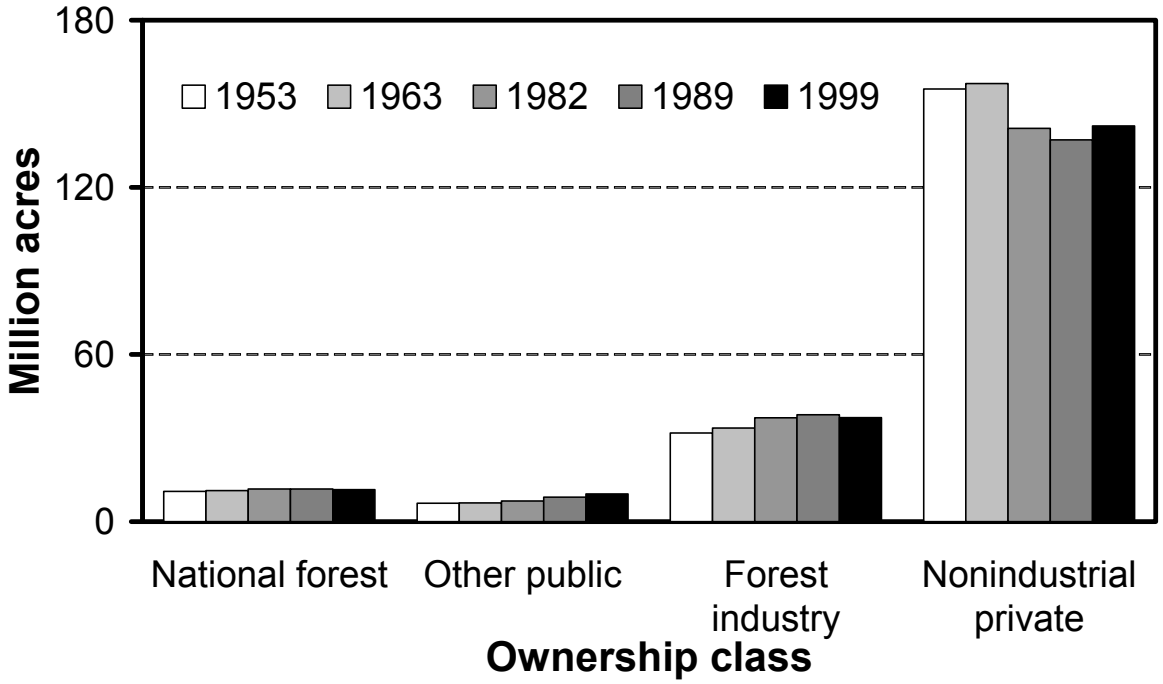

Figure 3.2.2—Timberland area by ownership class and year, Southern United States. Source: HLTH-1, Figure 6.

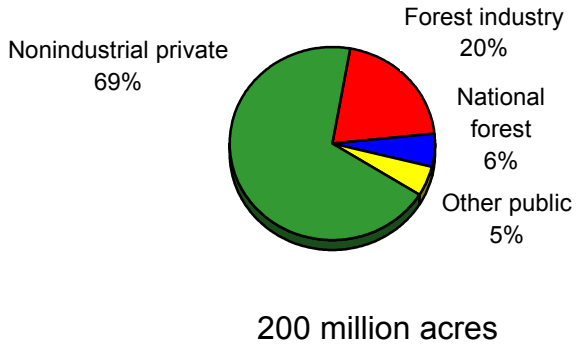

Figure 3.2.3—Distribution of timberland by owner class, Southern United States, 1999. Source: HLTH-1, Figure 38

The most substantial reduction in forest ownership since the 1950's has been in the farmer-owner category. The amount of timberland held by farmers has declined from 88 million to 35 million acres. Private individuals who do not farm hold an increasing share.

Between 1978 and 1993 the number of forest-land owners increased by 12 percent in the South and stood at 4.9 million in 1993. Of these, 84 percent owned tracts smaller than 50 acres. Indications are that this trend continued through the 1990's. The implication is that an increasing share of southern forests is held in smaller parcels (SOCIO-4).

3.2.2 Broad Forest Types

Primary Question:	HLTH-1: What are the history, status, and projected future of southern forests?
Related Questions:	TIMBR-1: What are the history, status, and projected future demands for and supplies of wood products in the South?

While the total area of timberland in the South has remained relatively stable, forest types have changed (Figure 3.2.4). Five broad categories of forest types are recognized by FIA: upland hardwoods (including oak-hickory and beech-birch-maple), lowland hardwoods (including oak-gum-cypress), natural pines (including longleaf, slash, shortleaf, and loblolly not established by planting), planted pines (all species), and mixed oak-pine. Pine forest types have experienced the most change. The area of natural pine has declined from about 72 million acres in 1953 to about 34 million acres in 1999. Planted pine has increased from about 2 million acres in 1953 to more than 32 million acres in 1999. Upland hardwoods have increased somewhat between 1953 and 1999. Lowland-hardwood area declined somewhat between 1962 and 1970 but has been essentially stable since the 1970's.

Changes in broad forest types are brought about by forest succession and by forest management. Data for the 1980's and 1990's show that 28 percent (3.3 million acres) of new pine plantations came from forest that was previously natural pine. Forty-seven percent (5.7 million acres) was derived from hardwood and oak-pine forest types, and another 25 percent (3 million acres) was derived from agricultural land. Over this same period, 9.2 million acres of natural pine were reclassified as hardwood and natural oak-pine types, reflecting a natural succession from pine species to more shade-tolerant species such as oaks and hickories, or harvesting of the pine component from these forests.

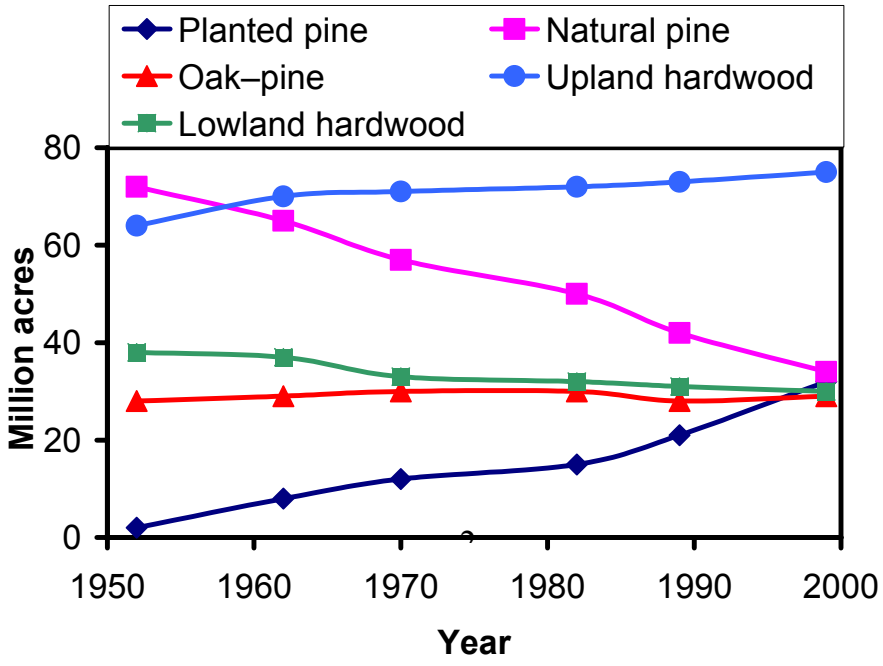

Figure 3.2.4—Trends in area of timberland by broad management type, all owners, Southern United States, 1953 to 1999. Source: HLTH-1, Figure 12.

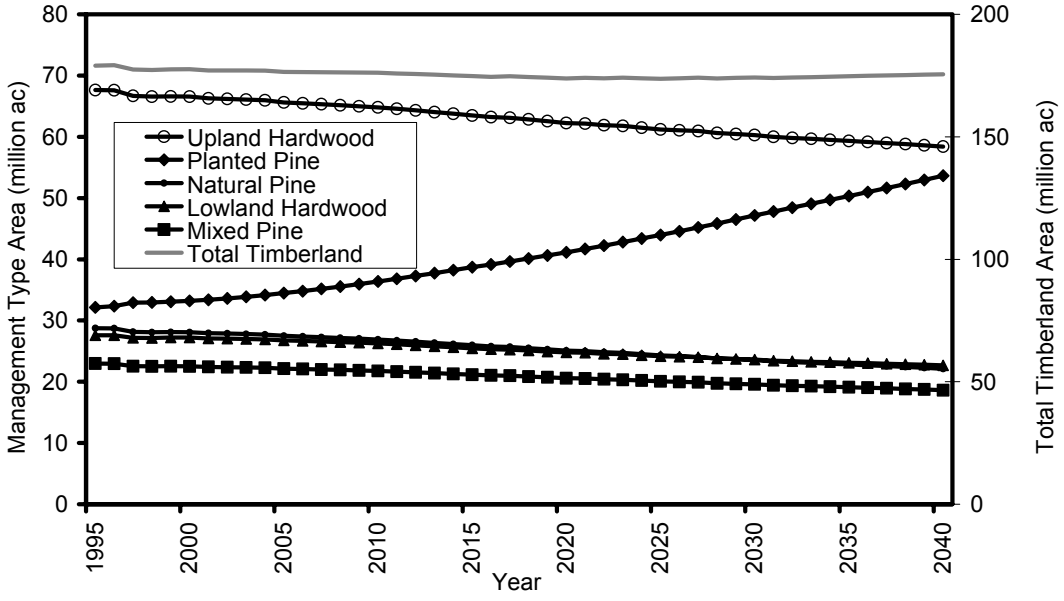

Figure 3.2.5—Forecasts of private timberland area by management type, 1995 to 2040. Source: TIMBR-1, Figure 15.

Upland hardwood acreage has been gradually increasing since the 1950's. Between the 1980's and the 1990's, 3.4 million acres of natural pine types shifted to upland hardwood. At the same time, 5.9 million acres of upland hardwood types were reclassified as natural-pine and oak-pine types. Hardwood forest types experienced the greatest amount of conversion (2.2 million acres) to nonforest uses over this period.

Lowland hardwood forest types declined in area between the 1950's and the 1990's, with most losses occurring between 1960 and 1970. Since then, losses have been more gradual. Much of the loss in the 1980's and 1990's resulted from reclassification to other natural forest types, but 600 thousand acres were planted to pine and 800 thousand acres were converted to nonforest uses during these years.

The area in pine plantations is forecast to rise by 67 percent from 32 million acres in 1999 to 54 million acres in 2040 (Figure 3.2.5). Areas of all other forest types are expected to decline at gradual rates (TIMBR-1). In total, nonplanted forest types are forecast to decline 25 million acres (17 percent) between 1995 and 2040. Twenty-three million acres of agricultural land are forecast to be planted over this same period. These forecasts indicate that forests of all types will be lost to urban uses and that gains in planted pine will come largely from planting of agricultural fields (Figure 3.2.6).

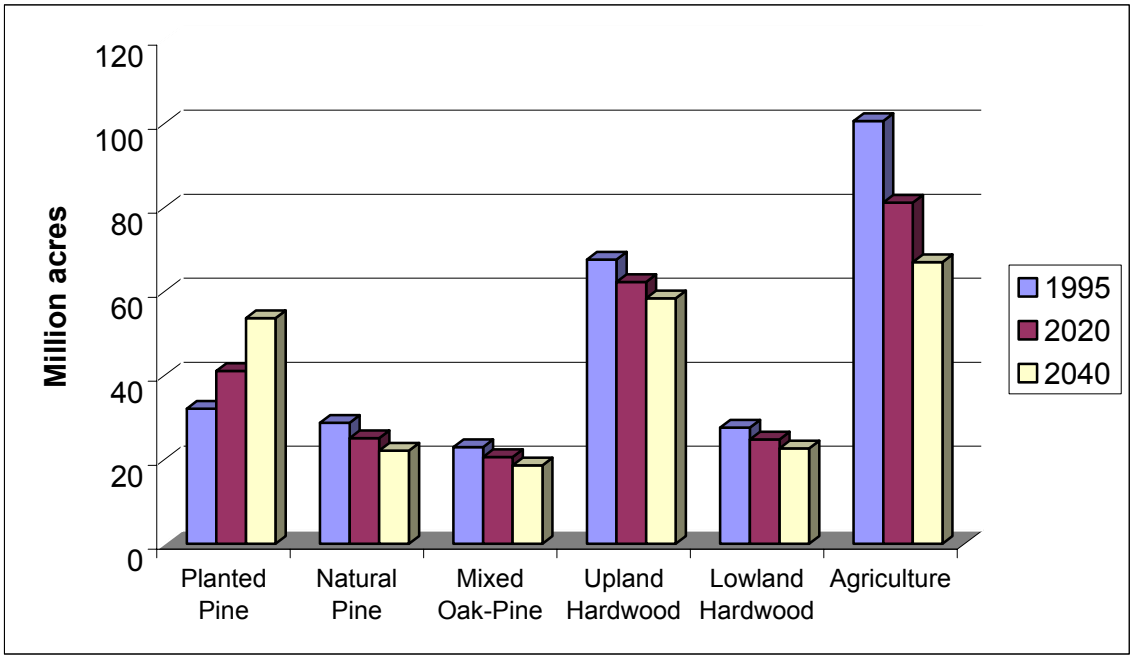

Figure 3.2.6—Forecast of the area timberland by forest types (million acres), 1995 to 2040.Source: TIMBR-1, data from several figures and SOCIO-1, Figure 10.

3.2.3 Landscape Structure

Primary Question:	SOCIO-1: How have land uses changed in the South and how might changes in the future affect the area of forests?
Related Questions:	TERRA-1: What are the history, status, and projected future of terrestrial wildlife habitat types and species in the South?
	TERRA-3: What are the likely effects of expanding human populations, urbanization, and infrastructure development on wildlife and their habitats?

Landscape structure refers to the spatial arrangement of forests and the habitats that they provide. The arrangement of forest cover has an influence over many functions of forest ecosystems, especially as wildlife habitat. For example, a large contiguous forest area has a large share of interior forest and relatively little edge-forest, while a patchy forest with the same total area has proportionately more edge habitat. In addition, configuration of forest cover influences the options available for active stand management. For example, small patches of forests may be less economical to manage for timber production due to economies of scale in timber harvesting, prescribed burning, and other treatments.

Interspersion of land uses, road construction, and the splitting of land parcels can cause fragmentation of forests. The effects are a decrease in the average size of contiguous forest patches, a decrease in the amount of forest, and losses in connectivity and interior habitat. Forest microclimate, species dispersion, and interspecies population dynamics are also influenced by fragmentation (TERRA-1). However, the effects of fragmentation on wildlife may be slight in areas with forest cover that exceeds 60 to 70 percent (TERRA-4). This is the situation across a large portion of the South.

On the other hand, afforestation of nonforest land can reverse fragmentation. That is, forest patches can become better connected if intervening nonforest areas are converted to forest cover.

Data are not available at the regional level for measuring changes in forest fragmentation over time. However, recently compiled data provide a "snapshot" of forest cover and fragmentation, thereby allowing comparisons of these measures among subregions of the South. Using maps derived from satellite images taken in the early 1990's, the extent of fragmentation in the South is shown by mapping two measures. One is the share of forest that is interior forest, defined as a forest "cell" surrounded on all sides by other forest cells so that it is not strongly influenced by environmental gradients emanating from edges. The other measure is "edge-influenced forest," defined as areas adjacent to nonforest uses (SOCIO-1).

The highest concentrations of interior forest in the South are in the Blue Ridge Mountains, the Cumberland Plateau, and the Allegheny Mountains (Figure 3.2.7). The Smoky Mountain National Park and a part of the Daniel Boone National Forest in Kentucky—just west of where the boundaries of Virginia, West Virginia and Tennessee meet—form the cores of these two areas. Other large areas where the share of interior forest is high include the Ouachita Highlands and Ozark Mountains of Arkansas, a region just north of the Mobile Bay, and the Apalachicola area in the Florida Panhandle.

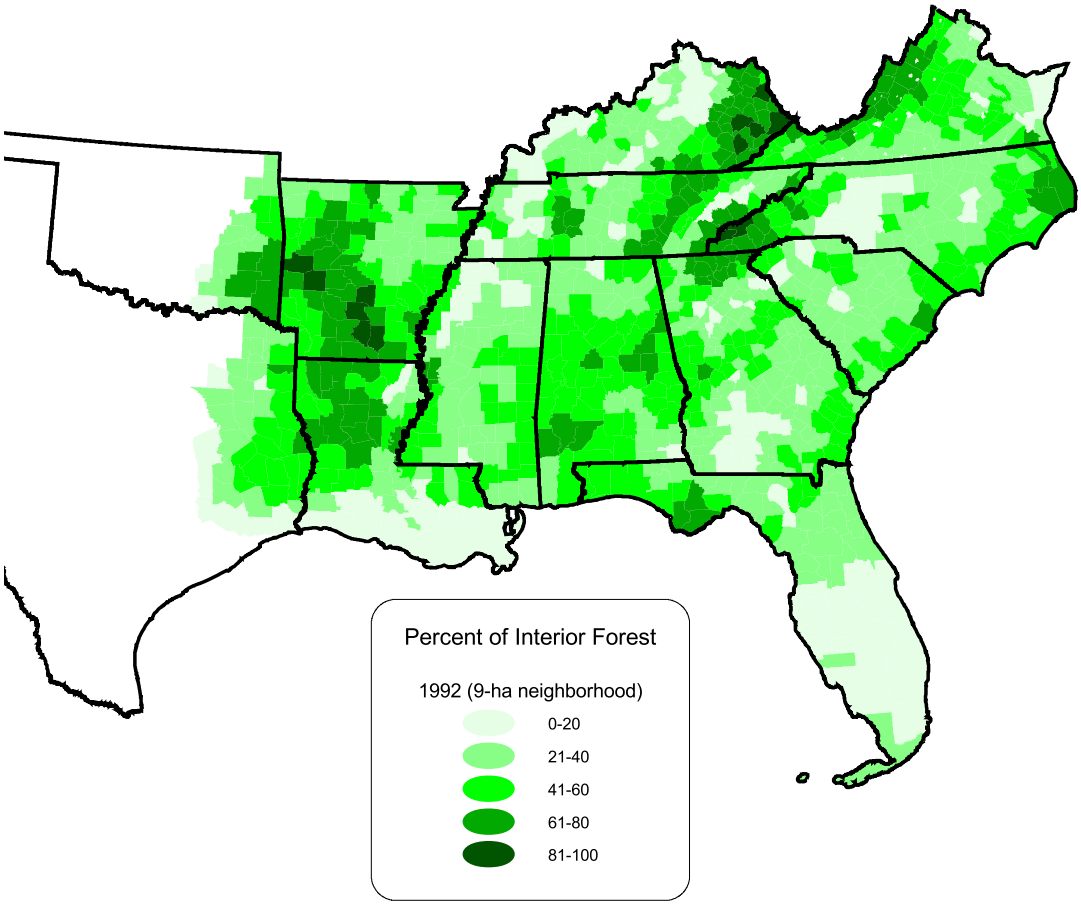

Figure 3.2.7—Percent of interior forest by county, 1992. Source: SOCIO-1, Figure 17.

Maps of edge-influenced forests (Figure 3.2.8) indicate several areas where forest is fragmented. The Southern Appalachian Piedmont (commonly referred to as the Piedmont) has a relatively high share of land in the edge-influenced category, especially in North Carolina. Two other contiguous blocks are in an area spanning northern Mississippi and western Tennessee, and an area west of the Cumberland Plateau between Alabama and the Ohio River. In both of these areas, agricultural cover types are interspersed with forest cover, fragmenting it into smaller patches and reducing the amount of interior forest.

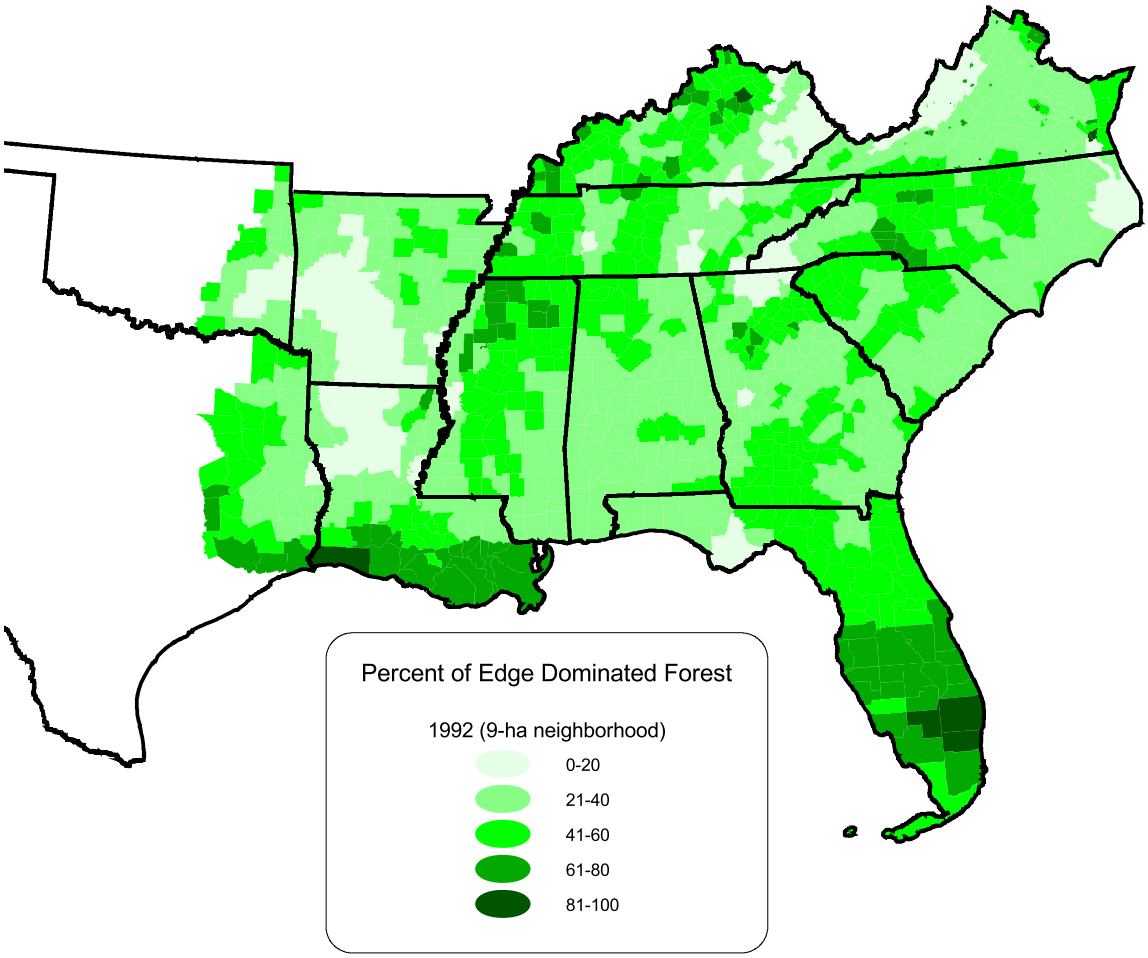

Figure 3.2.8—Percent of edge-influenced forest by county, 1992. Source: SOCIO-1, Figure 19.

Three parts of the South may be especially susceptible to fragmentation in the future due to current conditions coupled with forecast population growth (TERRA-1; SOCIO-1):

- The Piedmont is a heavily fragmented patchwork of agriculture, urban, and forest-land uses. Forecasts of urbanization in this ecoregion, would reduce forest cover, increase fragmentation, and cause other modifications to forests (SOCIO-1).

- In North Carolina, Tennessee, and Kentucky, the Blue Ridge, Ridge and Valley, Cumberland Plateau, and Allegheny Plateau ecoregions are susceptible to increased fragmentation. While much of this area is heavily forested, localized areas of urbanization and increasing road density could alter the structure of affected forested communities. A similar situation may arise in the Ozark and Ouachita mountains.

- In the Mississippi River Valley, West Coastal Plain, and Interior Low Plateau, forest habitat is scarce due to conversion of large portions of these forests to agricultural uses. Additional relatively small changes in forest structure in these ecoregions could reduce their overall

habitat suitability for many species.

3.2.4 Forest Inventory

Primary Question:	HLTH-1: What are the history, status, and projected future of southern forests?
Related Questions:	TIMBR-1: What are the history, status, and projected future demands for and supplies of wood products in the South?

Another way to track changes in forests is to monitor changes in tree biomass. This approach has long been used to examine timber supply issues because it provides a direct measure of the forest's capacity to produce timber products. It also provides insights into a forest's capture and sequestration of atmospheric carbon.

Evaluating changes in forests has long been a principal objective of FIA. The FIA measure of inventory most indicative of total biomass is "growing stock volume," measured as the volume of trees that either are or will likely be of merchantable quality. While the measure actually undercounts total biomass because it excludes certain tree species, all trees that are not yet 5 inches in diameter, and all other plants, it nevertheless serves as a useful biomass index. In the discussions that follow, "volume" refers to "growing stock volume" as measured by FIA.

Southern forests have accumulated substantial volume over the past 50 years (Figure 3.2.9). Between 1953 and 1999 the total volume increased 73 percent from about 148 billion cubic feet to about 256 billion cubic feet. This increase reflects the rapid growth of relatively young stands established after the 1930's. As the average age of these forests has increased, growth rates have declined somewhat. Most recent surveys show a slowing rate of accumulation for hardwoods and essentially a leveling off of softwood inventory.

The timber volume inventories of all 13 Southern States grew more than 50 percent between 1953 and 1999. Tennessee and Kentucky had the most prodigious increases and six States—Arkansas, Kentucky, Louisiana, Mississippi, Oklahoma, and Tennessee—more than doubled their inventories over this period.

Changes in inventories reflect the combined effects of growth, mortality, and removals. Removals measure losses of inventory due to harvest and conversions of forests to other uses. Trends in timber inventories have traditionally been evaluated based on the difference between annual net growth (biological growth minus mortality) and removal rates, often expressed as the Growth-Removal Ratio (GRR). A GRR greater than 1.0 indicates a net accumulation of volume. A GRR of less than 1.0 means that volume is decreasing.

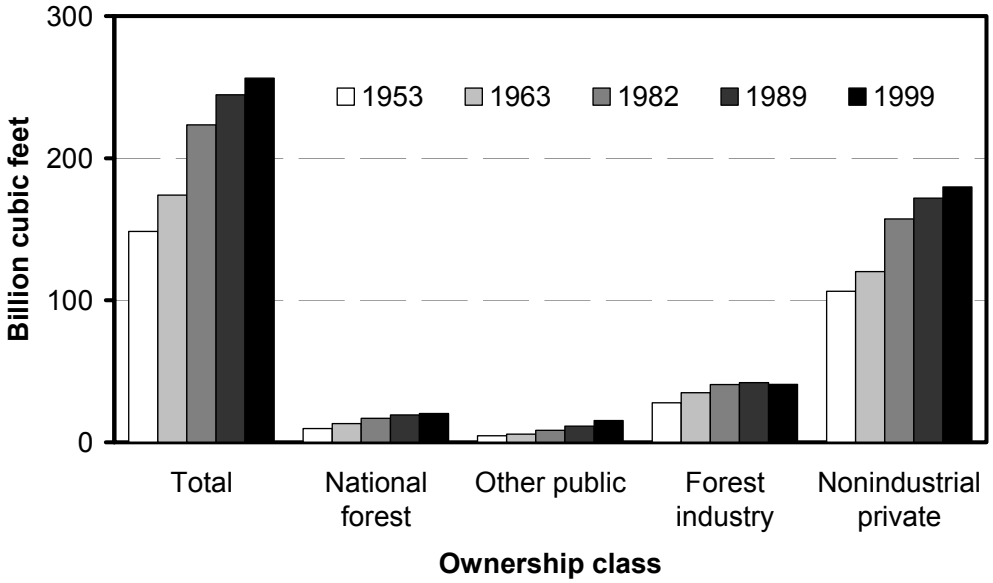

Figure 3.2.9—Volume of growing stock on timberland by ownership class and year, Southern United States. Source: HLTH-1, Figure 19.

For hardwoods, the GRR has exceeded 1.0 since the 1950's. In 1999 it stood at about 1.3, indicating that growth exceeded removals by about 30 percent (Figure 3.2.10). For softwoods, growth exceeded removals until about 1990. Since then, the GRR has been about 0.9, indicating that removals surpassed growth by about 10 percent. Models of growth and removals forecast that this situation is transitory and that softwood growth will soon exceed removals again. This is because the region is in a period of transition where pine plantations are expanding rapidly. As these young pines grow large enough to enter into the FIA inventory—forest analysts call this phenomenon ingrowth—measures of total softwood growth are expected to shift upward.

Anticipated changes in GRR are demonstrated by the 1989 and 1997 inventories of the Southeastern Coastal Plain of Georgia. In 1989, the forest survey indicated that the GRR was 0.98 but also noted that the rate of tree planting had more than doubled since the previous survey. The 1997 forest survey reflected this ingrowth and the GRR increased to 1.07. Meanwhile, the rate of planting continued to climb. Similar patterns of change are evident in Alabama and Mississippi, where recent planting activity has been high.

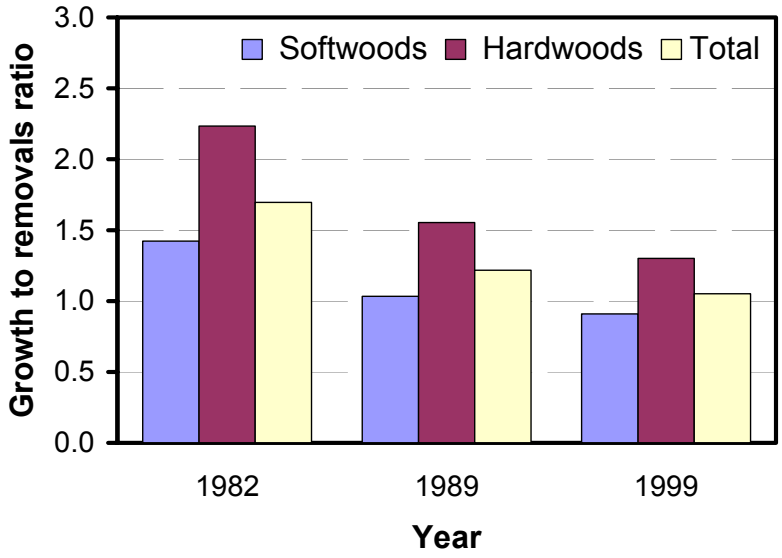

Figure 3.2.10—Average annual growth to average annual removals ratios of growing stock on timberland by softwoods, hardwoods, and year in the Southern United States. Source: HLTH-1, Figure 33.

We forecast that softwood growth will overtake and exceed removals by a slight margin in the next few years. As a result, softwood inventories are forecast to increase steadily between 1995 and 2040. For hardwoods, on the other hand, removals are forecast to exceed growth by 2025. Thus, total hardwood inventories are forecast to peak in about 2025 and then decline to levels just exceeding current levels by 2040. Inventories for individual States are forecast to peak and then decline at different times (see discussion in Section 3.1.3 and TIMBR-1).

Changes in mortality over time also are important. Since the 1950's, the rate of mortality for hardwoods (mortality divided by total volume) has fluctuated around 0.7 percent per year (Figure 3.2.11). Over the same period, softwood mortality has been increasing. The softwood mortality rate stood at about 0.55 percent per year in the 1950's and 1960's, nearly doubled by the 1990's, and now stands at about 1.0 percent of inventory per year. Reasons for this increase are unclear, but likely reflect several factors, including an aging softwood inventory on public and nonindustrial private land, increased susceptibility of offsite species to insects and disease, and a lack of thinning and other stand treatments in overstocked stands.

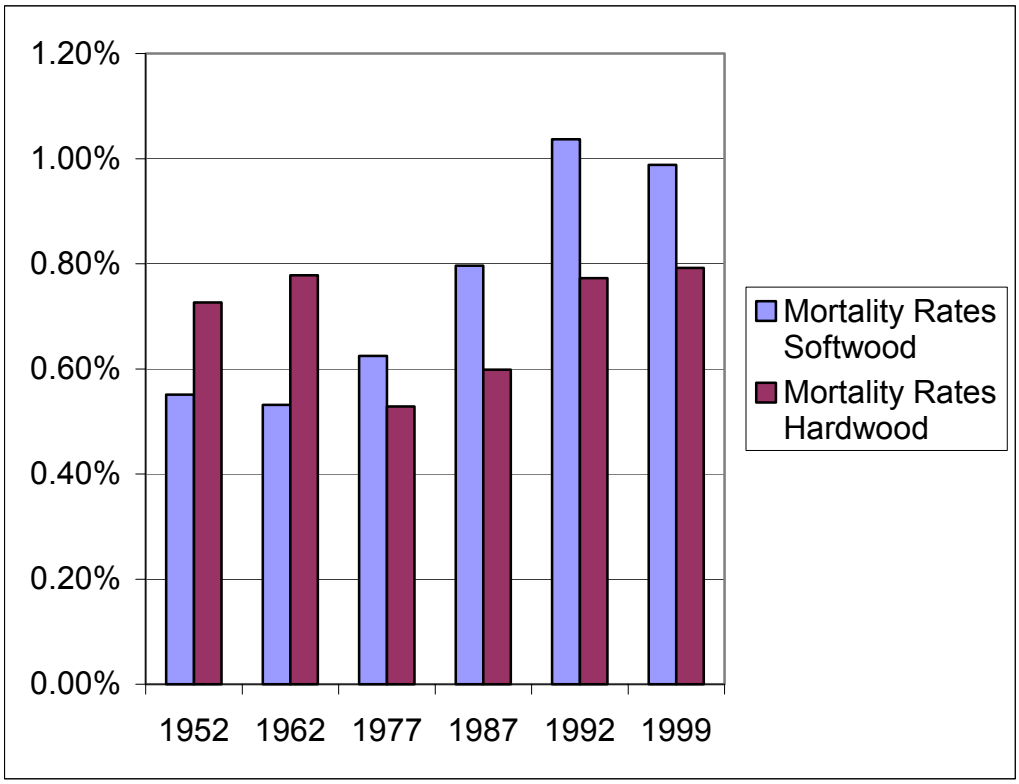

Figure 3.2.11—Mortality rates for hardwoods and softwoods, 1953 to 1999. Source: HLTH-1, Table 12.

3.2.5 Timberland Productivity

Primary Question:	TIMBR-2: What are the status and trends of forest management practices in the South?
Related Questions:	HLTH-3: How have abiotic factors including environmental stressors such as air pollution influenced the overall health of the South's forests and what are future effects likely to be?

In general, productivity is defined as the quantity of outputs produced from a given level of inputs. In forestry, there are several ways to measure productivity, including biomass production, the flow of values, and financial returns. The potential productivity of southern forests is examined here first in terms of biomass at both forest stand and regional scales. The feasibility of productivity gains is then evaluated by examining the financial returns to forest investments. Our analysis of timber markets (TIMBR-1) indicates that forest productivity is a key variable in forecasting not only harvest quantities and areas, but also the future condition of the region's forests.

A simple measure of productivity is the rate at which timber volume accumulates in a forest stand. This rate varies with stand age. Young stands accumulate volume rapidly and later approach a stasis where growth may barely offset mortality. Productivity also varies by forest type. Physical productivity can be assessed at a broad regional scale as a ratio of net growth to total inventory volume.

Forecasts of timber production and prices are critically dependent on estimates of future tree growth, especially in pine plantations. The productivity of pine plantations varies considerably with the type of management applied. The most intensive management approaches include planting of genetically improved seedlings, applying fertilizer, and controlling competing vegetation. These practices can yield about 65 percent more timber volume when compared to plantations that are not treated after planting, and more than double physical productivity when compared to natural pine stands (TIMBR-2).

Timber market models have generally assumed management intensity will be increased to capture this productive potential. Indeed, increased management intensity in pine plantations is a key component of the timber market forecasts discussed in Section 3.1.3. Softwood outputs are expected to increase by more than a third, and softwood inventory is expected to increase slightly between 1995 and 2040. Forest investments are forecast to increase the area of pine plantations from 32 million to 54 million acres by 2040. The area of the other broad forest types (natural pine, hardwood, and mixed stands) is forecast to decline from 149 million acres presently to 122 million acres by 2040 (TIMBR-1).

To test the sensitivity of timber market forecasts to assumptions regarding productivity, we examined an alternative scenario which assumed that 30 percent of expected productivity would not be attained—that is, productivity increases were set at 70 percent of current assumptions. As a result, softwood prices were forecast to increase and the increased prices led to additional investments in pine plantations when compared with the base case. The alternative scenario produced a forecast of pine plantation area that was 12 percent higher than for the base case (for a total of 58 million acres) in 2040 (TIMBR-1).

This suggests that reductions in the productivity of managed stands would have the somewhat counterintuitive effect of increasing the total area of intensively managed forests. Expected productivity gains could be offset by changes in institutional factors that restrict forest management options, changes in the physical environment that would result from air pollution or climate change, or increased insect or disease related mortality.

Research on the effects of air pollutants indicates that acid deposition probably will not have a measurable impact on forest productivity over the next 40 years. There is a trend away from sulfur and toward nitrogen as sources of acid deposition, and effects of oxides of nitrogen are mixed. Ozone pollution, on the other hand, is expected to increase and has the potential to reduce forest productivity by up to 10 percent per year (HLTH-3). Warmer conditions would worsen the damage caused by ozone, but this increased damage could be offset by increased productivity resulting from warming and elevated CO_2 concentrations. If, on the other hand, temperatures rise more than

currently expected, forest area and structure would change and the net effect on productivity would be negative. These results indicate the sensitivity of forecasts to assumptions about atmospheric conditions and illustrate the value of reducing uncertainty regarding these future conditions.

Forest pest-related mortality, potentially high in pine forests, is minimized by active management. Given the short rotation length (20 to 30 years typically) and active management practiced by the forest industry in the South, mortality rates would be lower on these lands; this is indeed the case (HLTH-1). If a similar management style were employed on the forecast additional plantations, mortality would appear to be manageable. On the other hand, with specific exceptions such as annosus root disease, plantations allowed to grow and age without cultural treatments or thinning will be susceptible to increased pest damage and consequent reductions in productivity.

3.3 Terrestrial Ecosystems

Intensive land uses over the past three centuries have altered the structure of the South's terrestrial ecosystems. Forces of change continue to alter the region's biota, and pressures are focused especially on several rare forest communities. These rare communities continue to be pressured by loss of area, fire exclusion, and disruption of hydrologic functions. Change has favored certain types of forests, such as loblolly pine and mixed upland hardwoods. Ongoing changes in these forest types also have implications for the structure and function of terrestrial ecosystems. We examine abundant and rare communities in the sections that follow. We then examine the effects of land use changes and forest management on terrestrial ecosystems. We conclude the section with a discussion of wildlife species of concern and conservation issues in the South.

3.3.1 Abundant forest communities

Primary Question:	HLTH-2: How have biological agents including insects and disease influenced the overall health of the South's forests and how will they likely affect it in the future?
Related Questions:	TERRA-1: What are the history, status, and projected future of terrestrial wildlife habitat types and species in the South?
	TERRA-2: What are the history, status, and projected future of native plant communities in the South?
	TERRA-4: What are the historical and projected future impacts of forest management and access on terrestrial ecosystems in the South?

Analysis of changes in forest types indicates ongoing transformation of forest conditions. The area of upland hardwoods is forecast to decline somewhat between 1995 and 2040, but will remain the forest type with the greatest area. Pine plantation acreage is forecast to increase through planting of agricultural land and harvested natural-pine and hardwood forests. Though these communities are considered abundant, they face continuing health challenges. Also, because of their extent, their structure and condition are especially important to the region's wildlife. The value of these forest types as habitat for wildlife depends largely on how they are managed.

3.3.1.1 Pine types

Pine planting will continue to be focused in the Coastal Plain and parts of the Piedmont, but we expect planting rates to increase the most in the western half of the region. Forest structure in plantations differs from that found in naturally regenerated stands. Their management is designed to focus site potential to maximize the growth of trees of a single species, and trees are spaced to maximize fiber production over a 20 to 30 year period. Retaining a narrowly focused stand structure requires considerable management effort. This is evidenced by about 2.5 million acres of plantations transitioned to other forest types since the 1980's. Thus, over time and without intervention, plantations often become more diverse in terms of tree species composition. Their value as wildlife habitat will vary depending on the type and variety of vegetative species that diversify the stand. This increased diversity is greater in plantations established following harvest of natural pine or oak-pine forests, because they retain biological legacies from the preceding forest type, especially when plantations are mixed in with naturally regenerated forests and wetlands as in the Carolina Coastal Plain. Plantations established on converted agricultural sites can develop considerable grass and forb diversity in early stages, but because they lack the biological legacies of earlier forests, their vegetative diversity is limited for a longer period of time (TERRA-4). Very dense stocking and use of herbicides can limit vegetative diversity throughout the entire rotation. The intensity of forest management has various effects on wildlife suitability. In addition to differences in forest structure, intensive pine management generally involves more frequent management activities. Depending on the circumstances (such as type of legacy, management strategy, density of stocking, use of herbicides, prescribed burning), these actions can disrupt, benefit, or have little effect on wildlife. Effects of management activities on wildlife are discussed in

Section 3.3.4.

Another less commonly recognized phenomenon associated with intensively managed forests is their invasion by exotic plants--additionally, other land uses have contributed to the spread of exotics in the South. Privet, kudzu, and other exotic shrubs and vines displace native plant species and vary in their benefit to wildlife. Kudzu and Japanese honeysuckle alone now occupy more than 7 million acres of land each (TERRA-3). In some areas, exotic vines can completely dominate the shrub and herb layer.

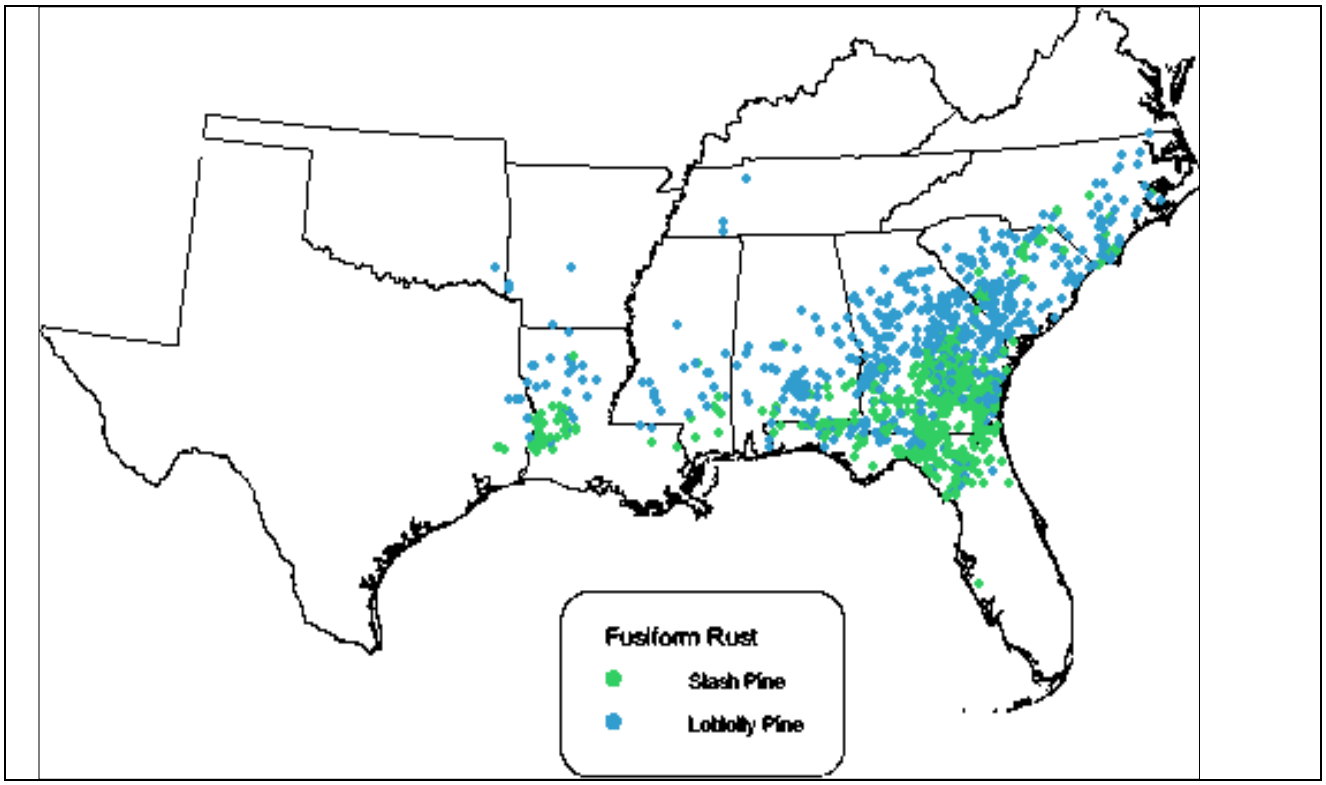

Figure 3.3.1—Incidence of fusiform rust based on data from Forest Inventory and Analysis (FIA) Program of the USDA Forest Service. Points on the map represent FIA plots expressing 10 or more percent infection of the species identified by spot color. Source: HLTH-1, Figure 4.

Expanded areas of pine forests in parts of the South have increased the availability and contiguity of host material for certain native pest insects and pathogens, especially southern pine beetle. However, short-rotation lengths and active management minimize what would otherwise be increased infestation risk. Damage from these pests is likely to be greatest in plantations that are not actively managed following establishment. These most commonly occur on nonindustrial

private ownerships. Pest-appropriate management activities—which may include lower stocking rates, use of prescribed burning, active pest suppression, and sometimes reducing the frequency of stand-disturbing activities—may lower the risk of spreading infestations in these types of forests.

Overall mortality rates for softwoods have increased from about 0.6 percent of inventory per year in the 1960's to 1.0 percent per year in the 1990's. We expect pine mortality to remain high, especially at the periphery of the natural range of many pine species—-for example, in Tennessee, Kentucky, and Virginia. In these areas especially, southern pine beetle will remain problematic for forest managers.

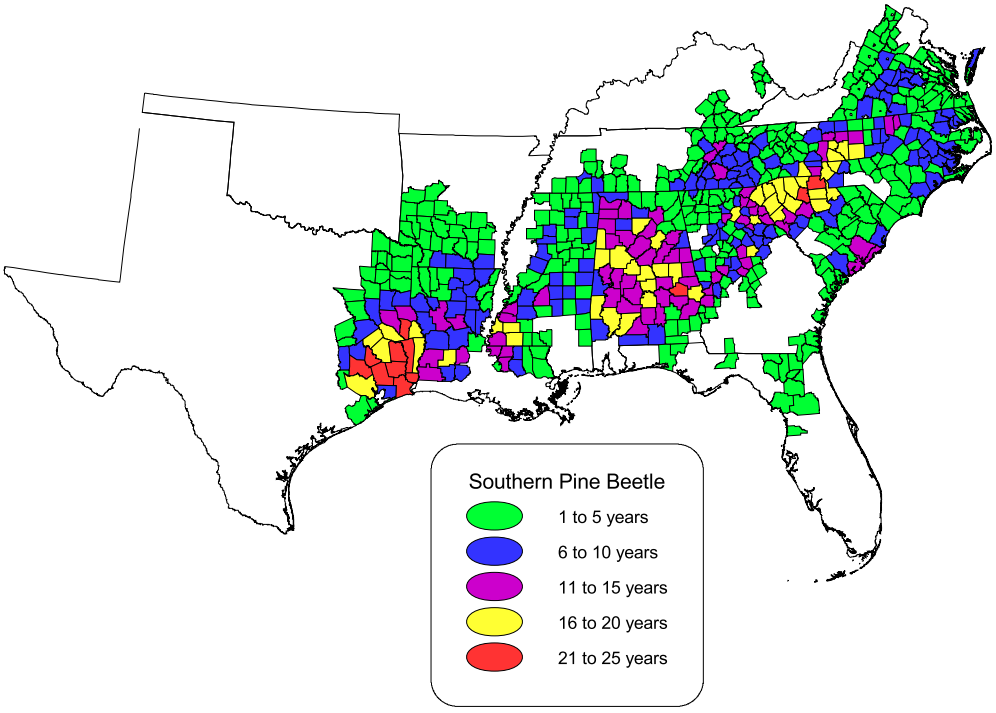

Figure 3.3.2—Counties in outbreak status for southern pine beetle; a 40-year summary. Source: HLTH-2, Figure 7.

With respect to forest pests associated with pine types, we found that (HLTH-2):

- Five native diseases in the South have substantial impact on forests and two—Annosus root disease and fusiform rust—have substantial commercial impacts on pine species. Fusiform rust is in epidemic status along the Coastal Plain from Louisiana to South Carolina (Figure 3.3.1). It causes heavy mortality of slash and loblolly pines. Annosus is more localized and

limited by site factors, but it can cause severe root disease in thinned stands if not treated. Littleleaf disease targets shortleaf pine and has encouraged the conversion of shortleaf sites to loblolly pine.

- Several native insects have substantial influence on forests. The insect with the most substantial economic impact and habitat impacts for the endangered red-cockaded woodpecker is the southern pine beetle, which reaches epidemic levels at irregular intervals and causes high rates of mortality over broad areas (Figure 3.3.2). It prefers shortleaf and loblolly pine forests, but also attacks other pine species. Longleaf pine, while susceptible, does not appear to be a preferred host species.

- Mature pine trees are more susceptible to damage from southern pine beetle than younger trees, so that public forests, with higher concentrations of older, more mature pine forests, are most likely to be attacked. "Spill-over" of epidemics onto adjacent private land will continue to be a significant resource management issue for public forests in the South. Likewise, planted pine on nonindustrial private forest land with little management experiences higher mortality from southern pine beetle. The risk of damage can be reduced by utilizing management practices that reduce stocking.

3.3.1.2 Upland hardwoods

The upland hardwood type gradually expanded in the South between the 1950's and the 1990's but has been in a state of flux for more than a century. Many areas were permanently transformed by chestnut blight, which eliminated American chestnut from its dominant role in mountain forests in the eastern portion of the South beginning in the 1930's. Recent expansion of upland hardwood acreage has resulted from a combination of natural succession of pine forests and removal of the pine component from mixed pine-hardwood forests. Currently, the greatest expanses of the upland hardwood types (generally oak-hickory) are concentrated in the Piedmont, the Appalachian Mountains, the Ozarks, and the Cumberland Plateau. Urbanization, along with increased harvesting of hardwood timber, will continue to modify these forests in important ways, especially in the Piedmont. While the area of upland hardwoods is forecast to decline only slightly over the next few decades, it is likely that these forests will become more fragmented in some areas, and in these places, will provide less interior forest habitat. In addition, indirect human influences related to increased population density will also be felt in these areas.

As with softwood forests, pathogens and insects have had important effects in hardwood forests and they continue to spread within the South. As was the case with chestnut blight, most of these organisms are non-native, or exotic, and control options are either ineffective or limited in their potential application.

- Oak Decline, a disease complex affecting oak species, could have long-term consequences for the species composition of hardwood forests in the South. It is prevalent in areas where oak species occupied the niche of American chestnut eliminated by the chestnut blight beginning in the 1930's. It is becoming especially widespread in the mountainous areas of

the Southern Appalachians and the Ozark and Ouachita Highlands, on dry and infertile sites. Drought appears to worsen its effects.

- Four exotic diseases have had or will have substantial impact on southern forests (HLTH-2). Each targets a single genus or species. Chestnut blight restructured Southern Appalachian forests, and the resulting trajectory of change has not completely played out. Based on current spread rates, Beech bark disease is expected to cause substantial mortality to American Beech and change its location in southern forests over the next 20-30 years. Butternut canker may completely eliminate Butternut from southern forests. Dogwood anthracnose has already led to widespread decline of dogwoods with resulting aesthetic, economic, and wildlife implications (see Figure 3.3.3).

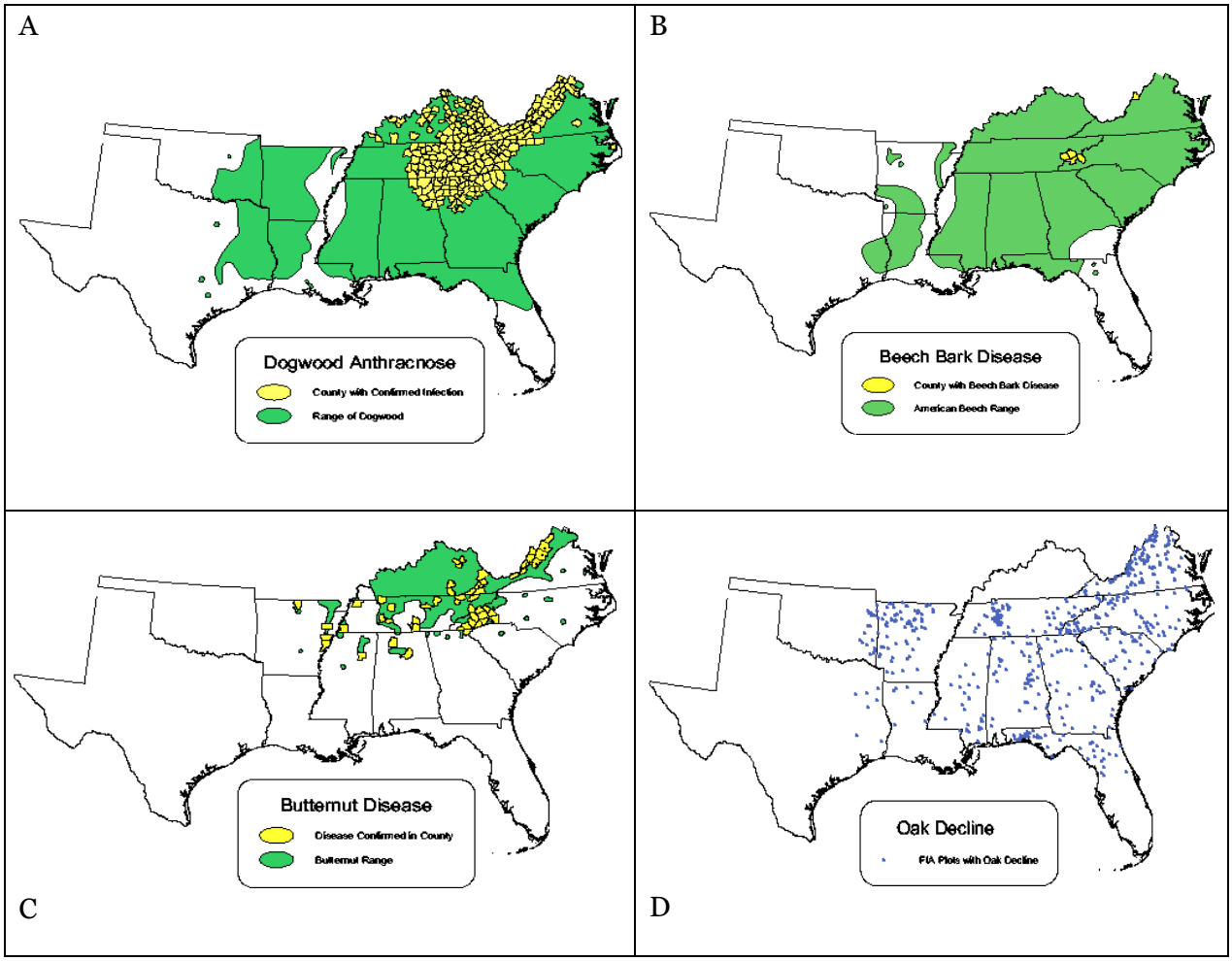

Figure 3.3.3—Various exotic diseases affecting hardwood species in the South. Source: HLTH-2, various figures.

- The hemlock wooly adelgid kills both the eastern and the Carolina hemlock and is currently

moving down the Blue Ridge from the Shenandoah Valley. It threatens both species' occurrence in the wild. (TERRA-3; HLTH-2).

- The gypsy moth continues its steady march from the North and is currently moving from Virginia into North Carolina. Based on current spread rates, this insect is expected to progress across the South over the next 20-30 years. Epidemics can last several years in a particular location and lead to the defoliation of most species, but oaks are most susceptible. Considerable alteration to forested ecosystems, including loss of hard mast, is expected where gypsy moth damage coincides with oak decline (HLTH-2).

Many of these forest health concerns can be complicated by the exclusion of fire. Absence of fire can alter species composition, but its reintroduction is difficult because much of the upland hardwood forest type occurs in or near heavily populated areas. Compounding the challenges of maintaining healthy hardwood forests is expected increased tree mortality that would increase fuel loadings and the risk of severe fires.

3.3.2 Rare forest communities

Primary Question:	TERRA-1: What are the history, status and projected future of terrestrial wildlife habitat types and species in the South?
Related Questions:	HLTH-2: How have biological agents including insects and disease influenced the overall health of the South's forests and how will they likely affect it in the future?

Several forest communities have become limited to only a tiny portion of their original range and thus may be disproportionately impacted by future changes. There are 14 critically endangered communities (where losses of more than 98 percent of their area have occurred since European settlement) and 25 endangered communities in the South (losses between 85 and 98 percent of area). Most of these communities are in the following seven classes (see TERRA-1):

- Old-growth—Less than 586,000 acres of forest area (0.3 percent) in the South is in an old-growth condition. Old-growth assemblages are diverse, and they exhibit unique structural characteristics such as multilayered canopies and large accumulations of woody debris. The largest tracts of these remnant forests are limited to a few ecological provinces. Most are on public land such as the Great Smoky Mountains National Park and the region's national forests. Some very small tracts occur on private land. While most publicly owned old-growth forest is administratively protected, factors such as air pollution and forest pests will continue to alter them.

- Spruce-fir forests are limited to high elevations in the Blue Ridge Mountains. These are very

scarce ecosystems containing unique assemblages of species with a high degree of endemism. They are threatened by a combination of exotic pests and environmental factors. The exotic insect having substantial impacts on these forests is the balsam wooly adelgid, which has already eliminated 95 percent of the mature Fraser fir from high elevation forests of the Southern Appalachians. A significant restructuring of this type of forest is anticipated. Additionally, soils in this community predispose the area to changes in stream chemistry and other ecosystem damage from increased acid deposition derived from nitrous oxides (HLTH-3).

- Wetlands, bog complexes, and pocosins have been reduced in total area by land use conversions and changes in hydrologic regimes. Bogs and pocosins provide habitat for many rare herpetofauna and birds. They also provide important refuges for species in landscapes that are dominated by agriculture and intensive silviculture. Fire regimes are crucial to the sustainability of many of these forests and its exclusion has substantially altered them.

- Bottomland and floodplain forests. Because they often occur on rich alluvial soils, a large share of these forests has been converted to agricultural uses, especially in the Lower Mississippi Alluvial Valley. Such forests, therefore, occupy only 20 percent of their original area. Certain forest pests can affect these forests. For example, the baldcypress leafroller, which defoliates and kills baldcypress, is prevalent in Louisiana swamps (HLTH-2). Hydrologic alterations also alter the condition and structure of these forests.

- Glades, barrens, and prairies are naturally treeless areas in Piedmont, Interior Plateau, Ridge and Valley, and Coastal Plain ecoregions of the South. These areas evolved under extensive fire regimes, and fire exclusion has caused substantial ecological modification and continues to impact remnants of these systems.

- Longleaf pine ecosystems once covered much of the South's Coastal Plain. They now occupy only 2 percent of their original range. The herb layer of these forests is one of the most diverse in the world. They are home to several threatened or endangered species, such as the red-cockaded woodpecker, and several species with high rates of endemism. Decline in these systems is attributable to several factors, including removal of original stands followed by fire exclusion, conversion to other pine species, conversion to other land uses, and the introduction of livestock. Brown spot needle disease infects longleaf pine seedlings and, therefore hampers efforts to restore the longleaf ecosystems across the South. Current concerns include continued urban development and difficulty in reestablishing fire regimes.

- Atlantic white cedar swamps have been reduced to 10 percent of their original range. They persist only in isolated small stands. As with pocosins, they provide for diverse wildlife refuges in intensively managed forest and agricultural landscapes.

Several increasingly rare types of wetlands—Atlantic white cedar swamps, bottomland forests, wetlands, bog complexes and pocosins—are concentrated on private land, so their future condition

is dependent on the decisions of their numerous owners. The spruce-fir and old-growth ecosystems are found mainly on public land. Old-growth is protected but is susceptible to invasion by exotic species, damage from air pollution, and restructuring due to fire suppression. Among rare forest communities, the spruce-fir ecosystem is currently under the most stress due to a combination of exotic insects and environmental stressors. Most remnant longleaf pine forests occur on private land and may be impacted by development, both directly through their conversion and indirectly due to the difficulty of providing the necessary fire regimes in areas of mixed ownership and high population density. Restoration efforts are underway, but challenges to restoring the longleaf pine ecosystem are great.

3.3.3 Effects of land-use changes

Primary Question:	TERRA-3: What are the likely effects of expanding human populations, urbanization, and infrastructure development on wildlife and their habitats?
Related Questions:	SOCIO-1: How have land uses changed in the South and how might changes in the future affect the area of forests?

The use and configuration of forest land can influence the suitability of forests as habitats for wildlife species. However, at this time, there are no regional level models for explicitly forecasting the effects of land use changes on wildlife. To address how land use could affect terrestrial ecosystems, we surveyed the body of research on the effects of various land uses and management on terrestrial animal species and found:

- Urban land uses have important impacts on bird populations. Urbanization restructures forest habitat by decreasing forest area and patch size while increasing edge relative to interior forest habitats (see TERRA-1). As a result, avian species composition is altered; nest predation increases, and habitats become isolated. Often bird diversity remains high, but there is a shift in species represented. For example, urbanization generally leads to declining populations of forest insectivores, Neotropical migrants, and forest interior specialists (TERRA-3).

- While the greatest impacts of urbanization seem to be related to habitat fragmentation and loss, increased human presence also has indirect effects. Evidence suggests that the presence of houses adjoining forest tracts can reduce the habitat value of those tracts for sensitive Neotropical migrant birds.

- Urban environments support fewer species of mammals than rural areas and tend to support habitat generalists rather than specialists. Highly urbanized settings support large populations of exotic species such as the house mouse and Norway rat. With green spaces in the urban area, many more species, especially small species, may persist. Mammalian predators such as bobcats and gray fox are generally excluded from habitat in highly

developed areas. Urbanization also tends to exclude specialized species of reptiles, amphibians, and invertebrates while generalists can persist in even highly urbanized areas. Fragmentation can isolate otherwise suitable habitats. Examples of urban-sensitive species include the gopher tortoise and the timber rattlesnake in east Texas.

- As urbanization reduces and fragments some forest areas, the remaining large forest tracts on public and private lands may increasingly contribute to the conservation of many sensitive wildlife species. Given the importance of landscape structure in determining the suitability of habitats in urban and agricultural areas (TERRA-3), maintaining habitat connectivity can enhance ecosystem function in these areas.

- Red imported fire ants have a substantial impact across an increasing range in the South. While most abundant in open habitats, they invade forests from along the margins created by roads and powerlines. These ants displace and/or prey on native arthropods, reptiles, amphibians, and rodents, disrupting food webs and restructuring forested ecosystems (TERRA-3).

- Several other exotic animals, such as feral pigs, cats, dogs, and exotic birds influence wildlife through predation, displacement of native species (especially birds), and habitat destruction (especially pigs). Localized impacts may be severe. For example, impacts of feral pigs have become very serious in rare wetlands in the Ozark-Ouachita Highlands. Population growth and expanding wildland-urban interfaces will result in growing problems with feral domestic animals (TERRA-3).

- Agricultural land is often interspersed with woodlots and other forest habitat. Habitat connectivity, which is often provided by vegetated fencerows, greatly influences the presence of birds and other species in agricultural areas. Isolated forest habitats can serve as ecological traps for some species by focusing populations in small areas along with a high concentration of nest predators (TERRA-3).

- Many bird species that depend on open habitats such as grasslands, prairies, savannas, glades, and barrens are now in serious decline in the Eastern United States. Declines are partially explained by the conversion of pastureland to cultivated row crops, the switch to “clean pastures” dominated by exotic, cool-season grasses and by the loss of fencerows as new agricultural technologies favor bigger fields.

- Forecasts of land-use change and measures of forest fragmentation suggest that bird species may be subjected to the most change in the Piedmont subregion (SOCIO-1; TERRA-1). Accordingly, we anticipate declines of Neotropical migrants and forest interior specialists in these areas. Implications for Neotropical migrants may be especially important, since this group of birds is experiencing global decline.

3.3.4 Effects of forest management

Primary Question:	TERRA-4: What are the historical and projected future impacts of forest management and access on terrestrial ecosystems in the South?
Related Questions:	HLTH-1: What are the history, status, and projected future of southern forests?

Forest management, by definition, affects the structure and distribution of forest conditions. Forest types have been dynamic in the South, with upland hardwood types increasing between the 1950's and the 1990's, lowland hardwood types essentially stable since the 1970's, and pine types in considerable flux. Net changes in forest are the result of several offsetting changes. For example, natural pine types are reclassified to upland hardwoods as a result of succession while some upland hardwoods are converted to planted pine. All forest types are converted to urban uses and agricultural fields are converted to planted pine (HLTH-1, and Section 3.2.2).

Silvicultural treatments can have important implications for wildlife. Timber harvesting, especially clearcutting, as well as afforestion of agricultural fields restarts successional processes. Young stands, especially those that follow timber harvesting, exhibit an increase in species richness and species diversity. Many wildlife species thrive in these early successional communities. After canopy closure, plant diversity generally decreases and wildlife use declines. Uneven aged management that encourages several age classes of trees can sustain benefits for many, but not all wildlife species due to the resulting stratified forest canopy. However, these benefits may lessen somewhat if stand entries are more frequent (TERRA-4).

Planted pine, while they are sometimes characterized as monocultures, vary considerably in their composition. Wildlife species that thrive in early successional habitats use plantations heavily during the first few years after planting, although habitat values decline with heavy stocking, application of herbicides, and other intensive management practices. Browse is abundant and several mammals graze these stands. Small mammals are abundant, thus raptor use is high. Many priority Neotropical migrants use pine plantations after the first thinning or use lower stocked areas where hardwoods are allowed to thrive in the understory (usually stands managed for sawtimber). Several Neotropical migratory birds use plantations early on, when insects and seeds are abundant. After canopy closure, plant diversity decreases and wildlife use declines.

Forest management can be augmented with techniques to directly enhance wildlife habitat. These include: leaving mature trees in a stand to enhance structural diversity, application of streamside management zones to retain landscape diversity, and retention of snags to provide nesting habitat (TERRA-4). Additional wildlife benefits may be obtained with natural regeneration techniques such a seed-tree cuts and shelterwoods, and with management practices such as mid-rotation thinning and prescribed burning.

Gauging the effects of forest management on mobile wildlife populations requires more than an understanding of stand-level dynamics. It requires insights into the overall landscape structure of forests within the region. Although this type of analysis is relatively new, several studies have examined the effects of forest fragmentation on wildlife species, especially birds. We found that (TERRA-4):

- Studies have documented declines in migratory bird species from isolated forest patches, especially where agricultural and urban uses represent substantial components of the landscape. However, in heavily forested areas—70 percent or more forest—these negative effects do not occur. Accordingly, in large portions of the southern landscape, these fragmentation effects are not a substantial concern. They include the Southern Blue Ridge, Cumberland Plateau and Mountains, and Ozark and Ouachita Mountains.

- Forest fragmentation and negative edge effects are most prevalent in Ridge and Valley, Piedmont, Interior Low Plateau, and the Mississippi Alluvial Plain where agriculture and development dominate the landscape. In these areas, forest operations may impact fragmentation effects on wildlife.

- In heavily forested areas, forestry practices may provide important benefits for forest breeding bird species through provision of early successional habitats. This is especially true for areas where existing hardwood forest structure is dominated by closed canopy stands and sparse understories or where dense pine stands and fire suppression exclude pine specialists.

Landscape configuration and fragmentation at fine scales may be critical for some species, especially amphibians, even in heavily forested areas. For example, persistence of pond-breeding salamanders requires access between terrestrial habitat and vernal ponds or Carolina bays. Roads and certain kinds of management practices can isolate these two habitat components. Spatial configuration of forest habitat is also an important factor in the recovery of Federally listed subspecies of black bears in Louisiana and the black bear subspecies of conservation concern in Florida (TERRA-4).

Across the South, more threatened and endangered species are affected by increased isolation of shrub-scrub and grassland habitats than are affected by scarcity or fragmentation of mature forests. The ultimate challenge for forest management then is to provide habitat conditions that support the array of grassland, shrub-scrub, and mature forest species occurring within the same landscape.

3.3.5 Wildlife species of concern

Primary Question:	TERRA-5: What conditions will be needed to maintain plant and animal species associations in the South?
Related Questions:	TERRA-2: What are the history, status, and projected future of native plant communities in the South?

Substantial alterations to forested communities have impacted several terrestrial species in the South. To enumerate and examine species of concern, the databases of the State Natural Heritage agencies were used to list species by their global conservation rank. The global ranks reflect scarcity for the entire range of the species. These ranks include: presumed extinct, possibly extinct, critically imperiled, imperiled, vulnerable, apparently secure, and secure. Species of "conservation concern" include those that are critically imperiled (extremely rare—observed at 5 or less locations or less than 1,000 animals—or otherwise vulnerable to extinction), imperiled (rare—observations in 6 to 20 locations, or less than 2000 animals—or otherwise vulnerable to extinction), or vulnerable (21 to 100 locations or 3,000 to 10,000 animals, or found locally in a restricted area). In addition, data on the status of threatened and endangered vertebrate species were compiled from the Department of Interior. We examined the status of terrestrial wildlife species and found:

- Of the 1,208 vertebrate species known to exist in the South, 132 are considered to be of conservation concern. Twenty-eight species are classified as critically imperiled.
- Seven southern terrestrial vertebrate species are now presumed extinct.
- The South is a center of amphibian biodiversity in the United States. Fifty-four amphibian species are classified as species of concern, and 19 are critically imperiled. Many amphibians require both wet and upland habitats, emphasizing the critical biological importance of wetlands and of ecotones (the gradients between wet and dry habitats). Wetlands are discussed in more detail in Section 3.4.2.

The South contains several areas where the number of endangered species is high, including the Southern Appalachians, Atlantic and eastern gulf-coast flatwoods, gulf-coast marsh and prairie, and peninsular Florida. Loss of habitat is the primary cause of endangerment of terrestrial vertebrates. Forests, grasslands, shrublands, and wetlands have been converted to urban, industrial, and agricultural uses. Other factors include environmental contamination and commercial exploitation. Florida and Texas are the States with the greatest numbers of endangered vertebrate species (Figure 3.3.4).

Table 3.3.1—Terrestrial species, species of concern, and critically imperiled species in the South by taxa. These numbers include Texas and Oklahoma in their entirety. Source: TERRA-1.

Taxa	Total Species	Species of Concern		Critically Imperiled Species	
	Number	Number	Share of total	Number	Share of total
Amphibians	170	54	0.32	19	0.11
Reptiles	197	40	0.20	3	0.02
Mammals	246	18	0.07	2	0.01
Birds	595	20	0.03	4	0.01
Total	1208	132	0.11	28	0.02

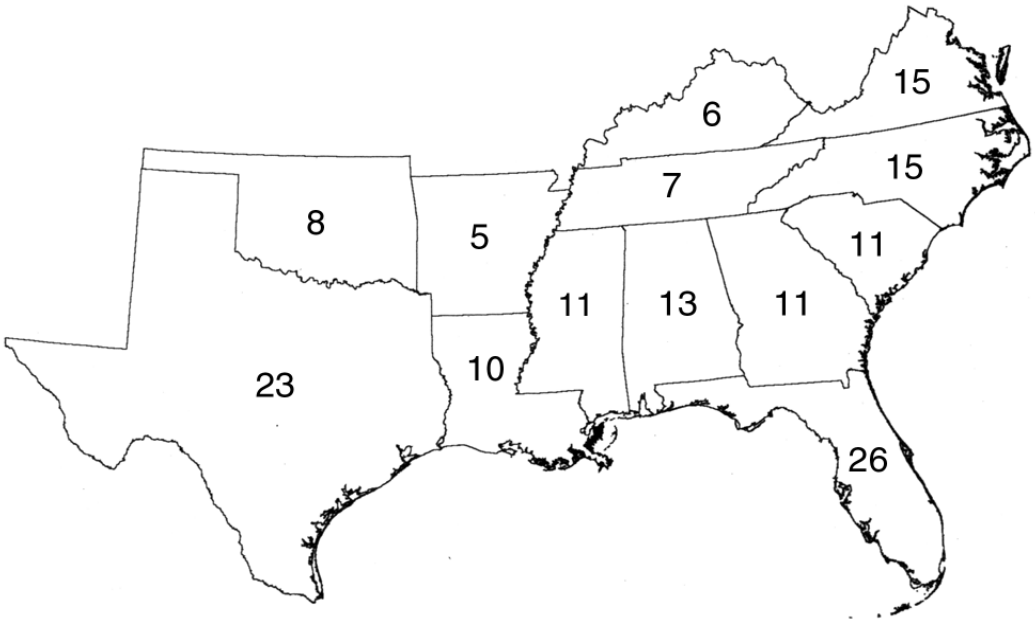

Figure 3.3.4—Number of terrestrial vertebrates in Southern States listed as endangered. Source: TERRA-5, Figure 8.

The South also has a large complement of rare plants. Rare vascular plant species are not evenly distributed throughout the South. Concentrations of rare species diversity occur in the Southern Appalachians, the Florida Panhandle, and the Lake Wales Ridge region of Florida. Rare species are also concentrated in the Ouachita Mountains and on the Cumberland Plateau (Figure 3.3.5, TERRA-2).

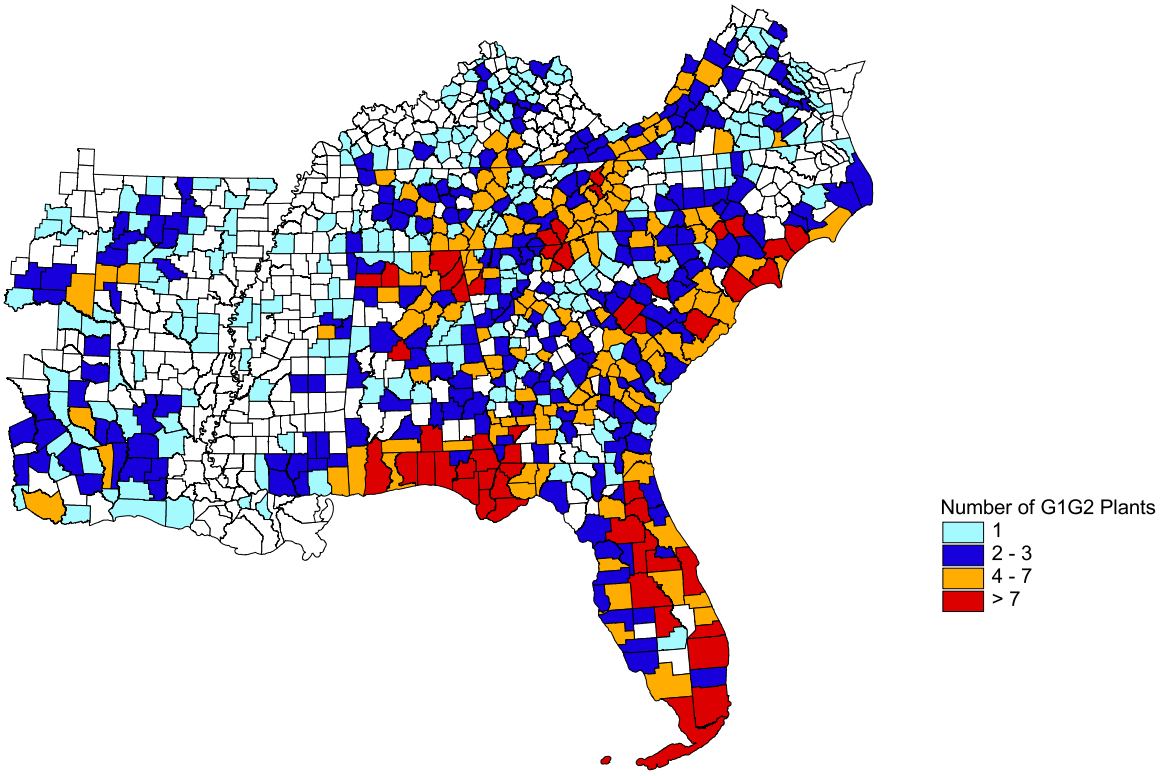

Figure 3.3.5—Distribution of critically imperiled (G1) and imperiled (G2) vascular plant species in the South, based on the number of occurrences in counties. Source: TERRA-2, Figure 2.

3.3.6 Conservation Issues

Management of public land includes protecting biodiversity through ecosystem or landscape-level management. About 11 percent of the South's forests are in a public ownership, and these areas tend to be concentrated in mountainous areas (Figure 3.3.6). For some rare communities, public lands are critical to conservation—for example, for protecting old-growth areas and high-elevation spruce-fir ecosystems in the Southern Appalachians. Often, however, rare plant communities and critically imperiled species do not occur on public land. The management of private forests, therefore, will have a substantial impact on the persistence of many species of concern in the South.

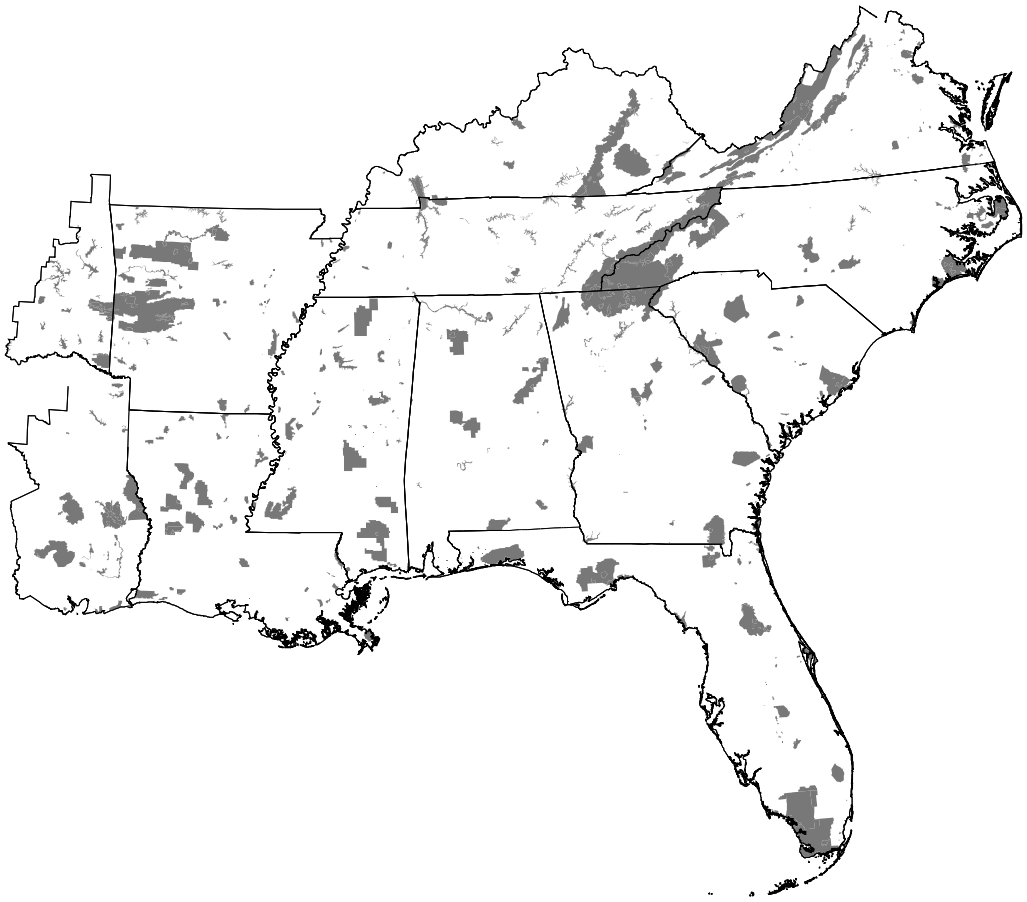

Figure 3.3.6--Distribution of public land in the South. Source: TERRA-1, Figure 23.

In the Coastal Plain and Piedmont, large blocks of public land are scarce, so ecosystem management strategies can only succeed through the cooperation of multiple landowners. Such collaborations are beginning to emerge. Land trusts have acquired land with high ecological value. Landscape-level consortiums are emerging to address ecosystem maintenance and restoration. Coordinated research and conservation have focused on understanding and restoring longleaf pine ecosystems.

The conservation value of public land may be high in some areas because public land can provide scarce interior forest habitat and older forests.

In urbanizing landscapes, public tracts can be factored into conservation strategies pursued by local planners. The principal vector of ecological change in these areas is fragmentation, and efforts to design development so some forest connectivity is retained could provide important habitat and other benefits, especially for Neotropical migratory birds.

The effects of human activities on forests are pervasive, even where there is no direct management activity. Hence, conservation requires careful monitoring of forest conditions and active management responses, even in remote areas.

The exclusion of fire remains a critical and widespread issue affecting the health of terrestrial ecosystems. The impacts of fire exclusion from longleaf pine communities are now well understood, not only for pine management, but also for other associated plant and wildlife species. The impacts on other systems, such as upland hardwoods, are less well known but likely linked to ongoing forest health problems. While some progress has been made, the effective reintroduction of fire into forest ecosystems remains a critical forest conservation challenge in the South.

3.4 Water Quality, Wetlands and Aquatic Ecosystems

Uses of land in the South over the past three centuries have dramatically altered watercourses and wetlands. Ongoing forces of change will continue to directly and indirectly impact water quality, wetland functions, and aquatic species. Still, the South's forests produce water of high quality, and the biological diversity of the South's aquatic ecosystems is substantial. In this section, we examine water quality and the effects of forest uses on water quality, forested wetlands, aquatic species of concern, and conservation issues regarding water and aquatic ecosystems in the South.

3.4.1 Water Quality

Primary Question:	AQUA-1: What are the history, status, and likely future of water quality in southern forested watersheds?
Related Questions:	AQUA-3: How have forest management activities and other forest uses influenced water quality, aquatic habitat, and designated uses in forested watersheds?
	AQUA-4: What are the implementation rates and effectiveness of BMP's in the South?

Land uses and management strongly influence the quality of the water flowing from forests. We examined the overall condition of southern water quality and primary sources of water quality impairment (AQUA-1), forest management's effects on water quality (AQUA-3), and the effectiveness of water quality protection efforts through best management practices (BMP's) employed during forest treatments (AQUA-4).

Water quality in the South has been heavily influenced by a long history of intensive land uses. Conversion of forests and forested wetlands to primarily agricultural uses started in the late 1700's and extensive logging began after the Civil War. These activities resulted in severe soil erosion and

heavy sedimentation of nearly all southern waterways. Urban expansion permanently altered hydrology and created chronic point and nonpoint pollution. The legacies of these actions are still evident and complicate our ability to discern the effects of current management and to measure trends in water quality. These historical legacies and the effect of ongoing urbanization continue to influence water quality, stream channel stability, and aquatic life in the South.

Beginning with the passage of the Clean Water Act in 1972, public agencies have focused increasing attention on minimizing pollution— including nonpoint source pollution—from land disturbing activities. However, water quality in southern streams and rivers remains variable.

We evaluated key aspects of water quality of southern waters, and found:

- Based on a national watershed characterization program, approximately 30 percent of the South has relatively good water quality, 36 percent has moderate water quality problems, and 15 percent has more serious water quality problems; approximately 19 percent of the South, primarily in western Texas, does not have sufficient information to provide a characterization of the status of water quality (Figure 3.4.1, AQUA-1).

- As reported by Southern States, the leading causes (pollutants) of water-quality impairment from 1988 to 1998 were siltation and sedimentation, bacteria and other pathogens, and nitrogen, phosphorous, and other nutrients (AQUA-1).

- The leading sources of water-quality impairment in the South from 1988 to 1998 were agriculture and urbanization. Approximately 70 percent of all pollution came from nonpoint sources (AQUA-1).

As for forest management effects:

- States reported an annual average of approximately 3,600 miles of rivers and streams as impaired by silvicultural activities from 1988 to 1998. Silviculture ranked 10th out of the 11 major sources of water-quality impairment during this time (Chapters AQUA-1 and AQUA-3).

- Southern forests play an important role in maintaining and improving water quality in the South. Forested watersheds have consistently been shown to have lower sediment and nutrient yields and better aquatic biological conditions than nonforested watersheds (AQUA-1).

- When properly implemented and maintained, silviculture BMP's are effective in controlling nonpoint-source pollution. In their absence, however, water quality can be significantly impacted by forest management activities (AQUA-3).

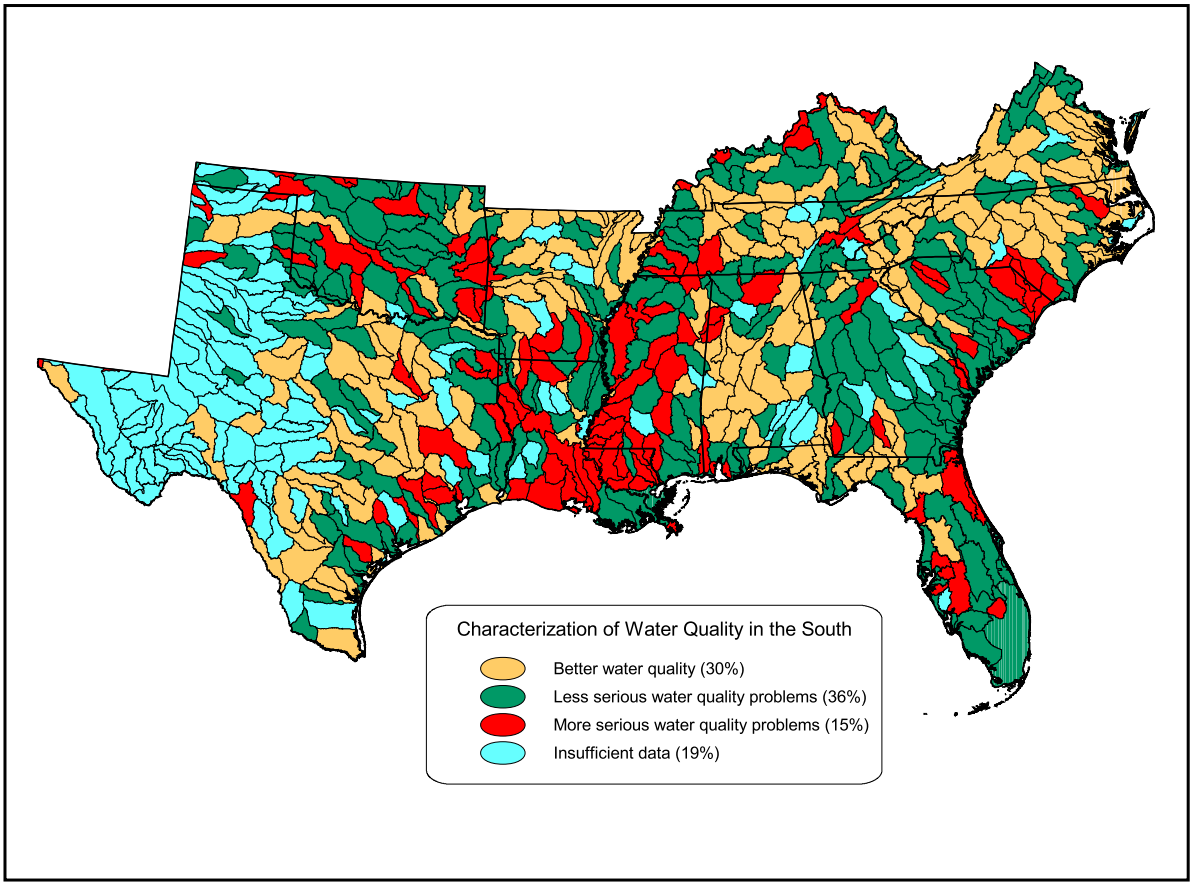

Figure 3.4.1—Overall characterization of water quality in Southern watersheds from the Index of Watershed Indicators data. Source: AQUA-1, Figure 4.

- All Southern States have adopted voluntary BMP's to protect water quality during silviculture operations. Twelve of the 13 Southern States have conducted surveys to measure BMP implementation—Oklahoma is in the process of conducting its first survey (AQUA-4).

- States report generally high rates of implementation. However, compliance rates vary from 35 percent to 100 percent depending on the State, ownership, or BMP category. Overall BMP compliance tends to be highest on public and industrial private land and lower on nonindustrial private land. Direct landowner assistance appears to be positively correlated with proper BMP implementation (AQUA-4).

- Differences in monitoring methods among States and within States over time preclude reporting of regional BMP trends (AQUA-4).

- There is very little information available on the cumulative effects of past and ongoing timber harvesting and management on overall watershed health (AQUA-1, AQUA-3).

3.4.2 Forested Wetlands

Primary Question:	AQUA-2: What are the history, status, and likely future of forested wetlands in the South?

The South has numerous types of forested wetlands, which provide a diverse array of water quality, flood attenuation, and wildlife habitat benefits. Wetlands of various types have experienced significant structural changes and permanent losses. While the rate of wetland loss is declining, the South has lost more than half of its wetlands between colonial times (1780) and the 1990's.

In the late 1990's, the 10 Southeastern States (the Assessment region minus Virginia, Texas, and Oklahoma) contained approximately 32.6 million acres of forested wetlands (AQUA-2). More than half of the region's wetlands are contained in the Coastal Plain provinces.

Forested wetlands are highly diverse but can be placed into three major categories: riverine, depression, and flatwoods.

Riverine wetlands represent the vast majority of forested wetlands in the South. They are located on floodplains and riparian corridors associated with streams and include deepwater swamps and alluvial floodplains that range in size from narrow riparian strips to broad alluvial valleys. The major water sources are overbank flooding and subsurface connections with stream channels. Riverine forested wetlands store water, intercept and cycle nutrients and toxicants, and provide environments for wetland flora and fauna. They may mitigate flood damage, enhance water quality, and support characteristic ecosystems. Because they provide linear connections across landscapes often dominated by other land uses, these types of wetlands also serve as important corridors for the dispersal of wildlife species.

Depression wetlands include pocosins, Carolina bays, pond cypress swamps, and mountain fens. These wetlands derive from topographic depressions and receive water from a variety of sources including precipitation, overland flow, and groundwater. As with riverine types, benefits are associated with water retention and filtration and provision of wildlife habitat. Most depression wetlands are located low in a watershed, allowing them to play an especially important role in removing sediments, nutrients, and pollutants. Because their vegetative structure is typically very heterogeneous, these areas support highly diverse plant and animal communities. Carolina bays are located throughout the Atlantic Coastal Plain, and cypress domes are located primarily in Florida. Both provide especially important breeding grounds for imperiled amphibians.

Mineral soil flats, predominately wet pine flats, are shaped by a combination of fire and water regimes. They are commonly found on areas between rivers—called interfluves—on extensive lake bottoms or on large floodplain terraces. The main sources of water are precipitation and slow drainage associated with a landscape of low relief. If subjected to periodic fire, these flats have very few trees. Frequent fire and an uninterrupted hydrologic regime yield a highly diverse and unusual floral assemblage. Their herbaceous species richness is considered to be among the highest in the Western Hemisphere.

Riverine wetland types dominate in the South, representing 91 percent of forested wetland area, compared to approximately 2.5 million acres of mineral soil flats and less than 1 million acres of depression wetlands. We found that (AQUA-2):

- All three types of forested wetlands have been and continue to be influenced directly and indirectly by development. According to the National Wetland Inventory, 3.5 million acres of southern forested wetland underwent changes between 1986-1997. Ninety percent of the changes were conversions to another wetland or aquatic habitat type. Of these conversions 95 percent were to scrub-shrub or emergent wetlands. During the same time period, approximately 119,000 acres of forested wetland went into urban and rural development, 112,000 acres to agriculture, and 102,00 acres to intensive silviculture. Draining and filling of wetlands impairs water storage capacity and therefore flood protection capacity and water filtration functions.

- Upstream urban development and certain agricultural and silvicultural practices can alter wetland functions.

- Changes in vegetation, species composition, soils, and wildlife use resulting from forest management activities are often transitory, especially when stands are naturally regenerated following harvest.

- The effects of silvicultural treatments on nutrient cycling and pollutant sequestration within wetlands are uncertain.

Drainage and bedding of wetlands can impact soils, hydrologic function, and some species of wildlife. This is an especially important concern for some amphibian species.

An examination of wetland history and status revealed:

- The 10 Southeastern States (the Assessment region minus Virginia, Texas, and Oklahoma) contain approximately 32.6 million acres of forested wetlands (AQUA-2). They represent 64 percent of the total in the coterminous United States.

- Forested wetland losses have been widespread, but have been concentrated in the Lower Mississippi Alluvial Valley—where losses were primarily to agriculture—and Coastal Flats .0of North and South Carolina—where losses have been to urbanization, agriculture, and silviculture.

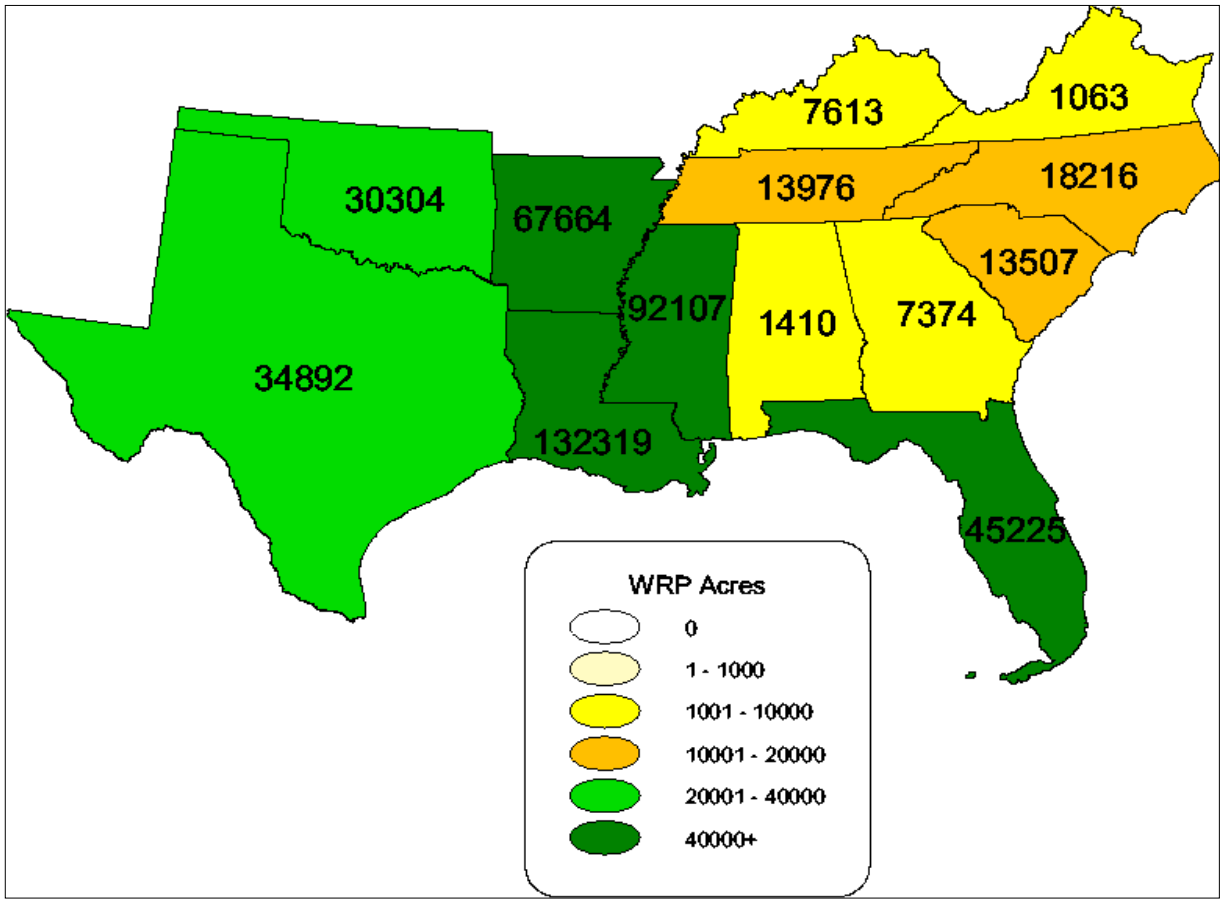

Figure 3.4.2—Number of acres enrolled in the Wetland Reserve Program, by State. Source AQUA-2, Figure 4.

- Rates of wetland losses have declined since the 1970's,largely as a result of Section 404 of the Clean Water Act, which regulates dredging and filling of wetlands. However, functional changes continue to occur in some forested wetlands as a result of continued urbanization, intensification of forest management, fire exclusion, and alteration of hydrologic regimes.

- Wetland restoration efforts pursuant to the Wetlands Reserve Program are concentrated in the Lower Mississippi Alluvial Valley (Figure 3.4.2). Tree planting success has often been acceptable, but restoration of the ecological functions of these wetlands is difficult to determine and presently unknown.

- Information on mitigation and restoration pursuant to Section 404 of the Clean Water Act is not systematically compiled and reported. Thus, successful implementation of required mitigation is not reportable.

3.4.3 Aquatic Species of Concern

Primary Question:	AQUA-5: What are the history, status, and likely future of aquatic habitats and species in the South?

The South's streams, riparian areas and wetlands contain a great diversity of aquatic life (AQUA-5). For example, 91 percent of the freshwater mussels described in the world are present in the South. Modification of aquatic and wetland habitats has greatly influenced this biota, and effects of past actions are in some cases particularly severe. For example, dam construction has irreversibly changed habitats for certain snails and freshwater mussels that depend on free flowing water.

To enumerate and examine species of conservation concern, the databases of the State Natural Heritage agencies were used to list species by their global conservation rank. The global ranks reflect scarcity for the entire range of the species. These ranks include: presumed extinct, possibly extinct, critically imperiled, imperiled, vulnerable, apparently secure, and secure. Species of "conservation concern" include those that are critically imperiled (extremely rare—observations include 5 or less locations or less than 1,000 animals—or otherwise vulnerable to extinction), imperiled (rare—observations in 6 to 20 locations, or less than 2000 animals—or otherwise vulnerable to extinction), or vulnerable (21 to 100 locations or 3,000 to 10,000 animals, or found only locally in a restricted area). We evaluated the status of the region's aquatic species of concern (AQUA-5) and found:

- Amphibians: Thirty-one amphibian species of concern, including 28 salamanders, 2 frogs, and 1 toad are located in the South. These rare amphibians are concentrated in three areas: the Southern Appalachians, the Florida Panhandle, and central Texas. Many species in the Appalachians are concentrated on national forests and national parks. In the Florida Panhandle, habitat is largely in private ownership (Figure 3.4.3).

  Mussels: The South contains the highest diversity of mussel species in the world; 91 percent of the world's known species occur here and almost 80 percent of them are endemic to single watersheds. The region has 191 mussel species of concern; 67 are critically imperiled. Among several key river basins, the Tennessee, Cumberland, and Mobile basins host particularly diverse populations of rare mussels (Figure 3.4.4). Because mussels are long-lived species (up to 100 years) population trends reflect habitat modifications that occurred decades earlier. Declines in mussels are most critically linked to channelization and damming of rivers and the associated modifications to streambeds, water flow, and sedimentation. Extirpation of fish species that serve as hosts to mussel glochidia (juvenile mussels), also contribute to mussel decline. The introductions of exotic species (Asian clams and Zebra mussels) have also accelerated the decline of native mussels.

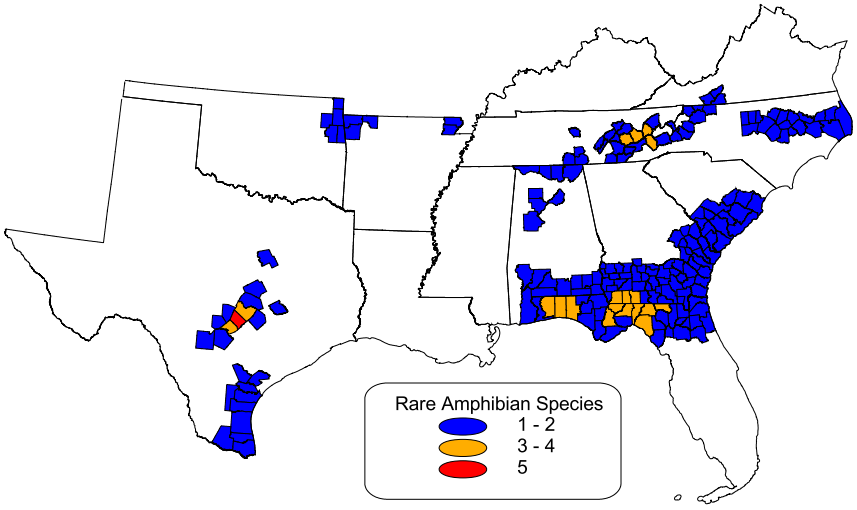

Figure 3.4.3—Distribution of rare aquatic amphibians by county. Source: AQUA-5, Figure 15.

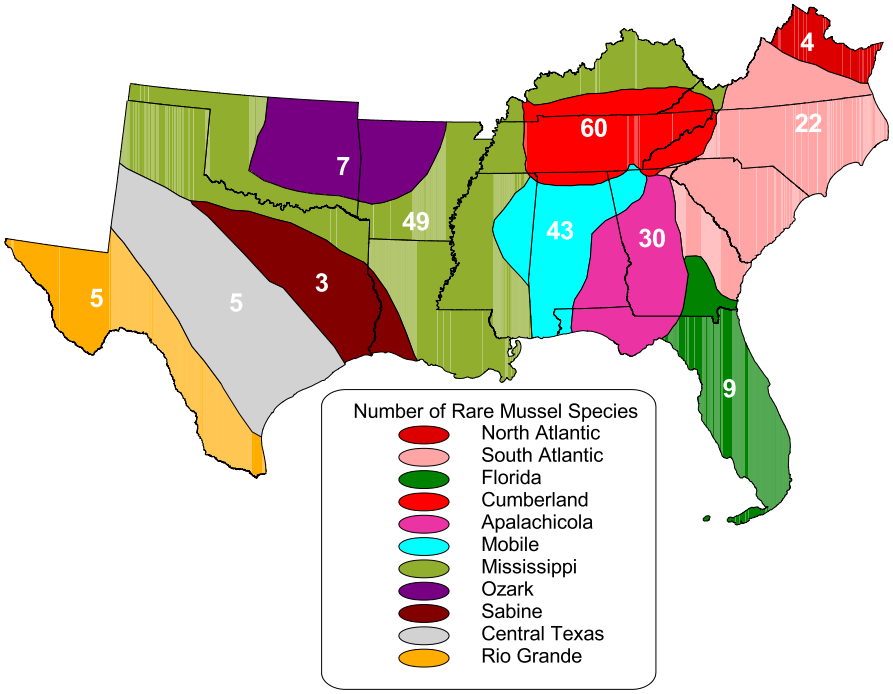

Figure 3.4.4—Distribution of mussel species by aquatic fauna provinces. Source: AQUA-5, Figure 12.

- Crayfish and other crustaceans: The South contains a broad diversity of crustacean species, including 159 species of concern and 60 that are critically imperiled. While they occur throughout the South, the area with largest concentration of crustacean species is the Florida Panhandle. Because the species are generally endemic to very small areas, modification of these habitats can have substantial impact on their viability. While crayfish

are generally very resilient—able to withstand transitory habitat modifications—habitat destruction in small areas can eliminate entire populations.

- Fish: The South contains 165 fish species of concern in 14 different families, and their occurrence is widespread. With the exception of central Mississippi and southern Florida, rare fish are present throughout the South (Figure 3.4.5). Many of these species are narrowly endemic—especially the darters, minnows, topminnows, catfish, gambusia, and sculpins. Because of this high degree of endemism, a few events or even a single event can have substantial impact on species viability. Declines have been associated with a wide variety of factors, including habitat modification, pollution, sedimentation, damming, introduced species, and interruption of water flow.

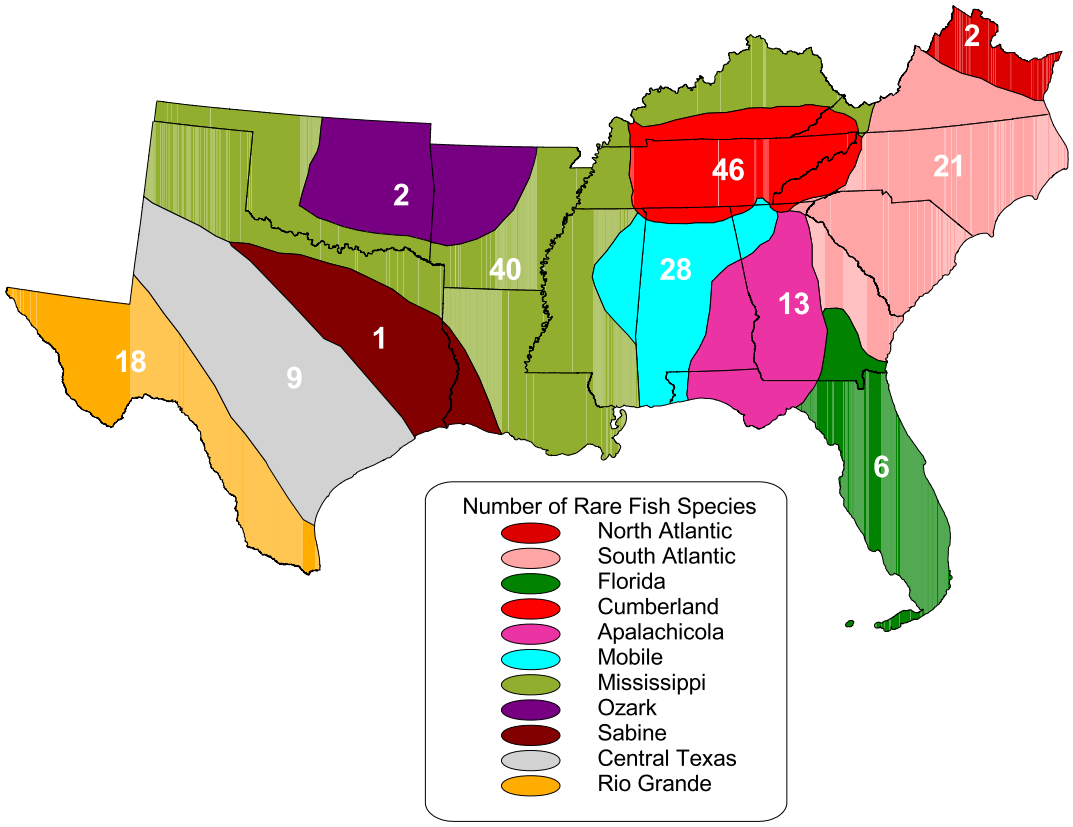

Figure 3.4.5—Distribution of rare fish species by aquatic fauna provinces. Source: AQUA-5, Figure 15.

- Snails: The South has 127 snail species of concern: 104 utilize stream habitat, 22 are found in springs and caves, and 1 is a lake snail. The snails found in springs and caves are narrow endemics concentrated most in Florida. They are especially susceptible to groundwater contamination and sedimentation. Eighty-nine of the 100 stream species are in the Tennessee and Mobile River Systems. Because they require free flowing water, damming

has had the greatest impact on these species. Remnant subpopulations are isolated, thereby limiting within-population genetic variability. Snails are also susceptible to pollution and to predation and competition from exotic species (e.g., Zebra mussels).

- Insects: One hundred and seventy six insect species of concern—including 64 stoneflies, 60 caddisflies, 31 dragonflies and 4 damselflies—are found in the South. Their nymphal stages require clean flowing water for effective feeding. Adults forage in adjacent terrestrial habitats. Declines have been strongly associated with dams, which reduce flow and allows for sedimentation of habitat. All of these species are vulnerable to further sedimentation and pesticide pollution.

- Reptiles: Nineteen species of concern, including one critically imperiled species, are found in the South. Many of these species are located in a large contiguous area stretching from central and southern Mississippi and Alabama to the Florida Panhandle. While these species are generally resilient, they are narrow endemics and so especially susceptible to local events. Specific threats include harvest for pets, indiscriminant killing, and damage to nests.

3.4.4 Conservation Issues

Primary Question:	AQUA-2: What are the history, status, and likely future of forested wetlands in the South?
Related Questions:	AQUA-5: What are the history, status, and likely future of aquatic habitats and species in the South?

Roughly half of the South's forested wetlands were lost between colonial times (1780) and the 1990's, primarily through clearing for agriculture. In the last decade, attention has begun to focus on restoring these areas, primarily in the Lower Mississippi Alluvial Valley where the most extensive loss of forested wetlands has occurred. Much of the restoration activity has been funded through the Wetland Reserve Program, which encourages afforestation of agricultural areas and supports conservation easements of up to 30 years.

Through the Wetland Reserve Program and several other restoration programs, about 195,000 acres in the Lower Mississippi Alluvial Valley have been replanted. However, the full restoration of wetland functions requires much more than tree cover. The effects of massive deforestation, extensive drainage systems, and channelization of streams and rivers make restoration of geomorphic, hydrologic and ecological processes extremely difficult. Wetland restoration activities will require long-term efforts extending far beyond initial tree planting.

A regulatory effort is the mitigation of wetland losses. These projects, carried out under Section 404

of the Clean Water Act, have been applied in several locations. However, a lack of systematic record keeping and monitoring prevents a regional assessment of their effectiveness. Some local assessments of these programs indicate that they may have only limited success in replacing the wetland functions lost through permitted conversions.

This Assessment of aquatic species highlights the prevalence and importance of endemism, in which a species' range is limited to a narrow geographic area. Crayfish, reptiles, fish, and snail species of concern are predominantly endemic. As a result, local actions can have substantial impacts on local species persistence, so that in some cases altering even small amounts of habitat can have significant implications. This potentially disproportionate impact of small actions places a high value on disseminating information on the locations and natural histories of endemic species.

Several focal areas for aquatic species are defined by this analysis. One is northern Florida, including the Panhandle, which has a concentration of rare reptiles, amphibians, snails, and crayfish. Rare mussels and snails are concentrated in the Mobile and Tennessee River Systems. The Southern Appalachians also have a very high concentration of the rare amphibians. These are areas where aquatic ecosystems are especially susceptible to structural changes in aquatic and adjacent terrestrial ecosystems.

Forest management usually has a relatively small role to play in the persistence of aquatic species. Habitats of mussels and snails have been completely restructured by damming and sedimentation from large-scale land use conversions. These impacts are essentially irreversible. For some species, forest management approaches play important roles in species persistence. Best Management Practices that reduce sedimentation and maintain streamside vegetation are especially important in protecting species that depend on streamside habitats. These include crayfish, amphibians, snails, and insects, especially in areas of concentration defined above. Conversely, forest practices or other activities that disturb habitats along streams can have a disproportionately significant impact on certain aquatic species.

4 Discussion

4.1 Broad Findings

Currently several forces of change are altering southern forests, raising questions about the sustainability of their functions and values. The first steps toward achieving their sustainability are to understand and anticipate the forces of change that shape forested ecosystems. Ultimately, sustainability requires that society manage change. Today's actions will influence whether and to what degree future generations will continue to benefit from the unique, inherent values of southern forests.

This Assessment has taken steps toward a fuller understanding of forest conditions and potential for their change by (1) identifying the forces of change that continue to reshape forests, (2) describing current resource conditions and their possible futures, and (3) highlighting where additional information is needed to fully identify and deal with concerns and opportunities. The

findings of this Assessment have led us to some broad observations about the status and possible future of southern forests:

- **Several forces are affecting the condition of southern forests**. The South is an economically, culturally, and ecologically complex region, and multiple forces of change are simultaneously affecting forest conditions. Timber harvesting and management and land-use changes into and out of forest cover influence forest area, structure, biodiversity, and water quality. Other human influences, such as atmospheric pollution, exclusion of fire from fire-dependent communities, and the introduction of exotic plants, diseases, and insects continue to reshape the composition, productivity, and ecological function of forests. Such influences are pervasive and difficult to predict and manage. All of these forces interact in their effects and will play out differently in different parts of the region. As a result, the extent, structure, and health of forests of the South are changing and will continue to change in the future.

- **Urbanization has a substantial impact on the extent, condition, and health of forests.** Among forces of change, urbanization will have the most direct, immediate, and permanent effects on the extent, condition, and health of forests. While urban uses currently represent a small share of land in the South, they are expanding rapidly. Forecast models predict that about 12 million acres of southern forests will be urbanized between 1992 and 2020. Nineteen million acres of forest are forecast to be developed between 2020 and 2040. In addition, population growth in rural areas means that more forests are increasingly influenced by human presence. In these areas remnant forests are becoming more fragmented. An important and pervasive direct result of urbanization of southern forests will be increasing limitations on forest management options, such as prescribed burning, that are necessary to maintain productive and healthy forests.

- **Population is growing and the social context is changing.** From 1980 to 2000, total population increased at a higher rate in the South than in the Nation. Through the 1980's, population growth in the South was focused primarily in urban areas. Many rural areas experienced population losses. Since then, populations increased in nearly all of the South's counties, expanding the interface between people and forests. The demographic profile of the region has changed toward a more urban population. These demographic changes are reflected

  in attitudes and values held about the region's forests. Public values about forests vary among sectors of the population and include both commodity and biocentric views.

  In urban areas and at their periphery, certain forest benefits are becoming increasingly scarce. Among these are opportunities for forest recreation. While the demand for recreation will increase as the population grows, recreational access to private land is expected to continue to decrease. As a result, congestion and competition between recreation user groups for access to and use of the region's public forests will increase.

- **Total forest area within the South is forecast to remain stable, but subregional and compositional changes will continue.** The South has rebounded from widespread deforestation of the early 1900's to become a heavily forested region. While the total area of forest has remained relatively constant over the past 30 years, 1 to 2 percent of forest land moved into or out of forest cover each year. We forecast little change in the total area of forests between 1995 and 2040, as losses of forests to urban uses are expected to be offset by conversions of agriculture land to forest. Urban development is forecast to be concentrated in the eastern part of the region and conversion of agricultural land to forest cover in the west, resulting in an overall westward shift in forest area as well changes in shares of forest types. These shifts in forest area and composition will alter the region's forests in ways that could be significant in affected areas. For example, loss and fragmentation of forests in some areas and an increasing share of pine plantations in others could have important localized economic and ecological implications.

- **Timber production is forecast to expand but not deplete forest inventories below present levels.** While the total area of forest land has remained relatively stable and harvests have expanded since the 1970's, the timber inventory on these forests has increased by more than 70 percent. Softwood inventories leveled off in the 1990's, but recent inventories and model forecasts indicate that they will expand as new and anticipated pine plantations grow to maturity. Hardwood inventories continued to increase through the 1990's, but at a decreasing rate. A region-wide trend of increasing removals relative to net hardwood growth is forecast to continue, resulting in the total inventory of hardwood forests peaking in 2025, then declining to about current inventory levels in 2040. While region-wide removals are forecast to exceed growth in 2025, this occurs at least 10 years earlier in four States. As with softwoods, additional investment in hardwood management could increase future growth and inventories of these forests, but this response has not yet been observed.

- **Investment in pine plantations is forecast to continue to expand to meet increased softwood demand, resulting in some changes to the ecological characteristics of southern forests.** Historically, private landowners in the South have responded to rising softwood timber prices by investing in tree planting and more intensive management. The result has been an increase in the area of pine plantations in the South, from about 2 million acres in 1952 to 32 million acres in 1999. Forecasting models predict that pine plantation acreage will increase to 54 million acres in 2040. These new pine plantations, which will be derived from the afforestation of agricultural lands and conversion of hardwood, natural pine, and mixed pine/hardwood forests, enhance softwood timber productivity and concentrate timber harvesting on fewer acres than would otherwise be necessary to meet demand. For example, plantation forests accounted for 15 percent of timberland and 12 percent of total growing stock volume in the 1990's, but 43 percent of softwood net annual growth and 35 percent of annual softwood removals (HLTH-1). Increased pine plantation acreage could also result in varying ecological changes, depending on stand origin and management. For example, young planted pine stands provide early successional habitats within which many species thrive. Subsequent management activities however, largely determine plant diversity and

habitat structure. While these dynamics have been studied at the forest stand level, they are not well understood at a broader landscape scale.

- **Changing land use and harvest patterns will have important impacts on people**. Land use and forest management changes can influence people in a variety of ways. Historically, the southern economy has been inextricably tied to various uses of its land base. The wood products industry, for example, currently accounts for about 6 percent of regional employment and 8 percent of income. Forecasts of increasing timber harvests imply more jobs in the wood products sector, especially outside the traditional core timber production areas. Forests also contribute to the quality of life by providing recreation opportunities, visual backdrops, and a variety of environmental amenities. Because people derive value from the landscape condition in which they live, abrupt changes in its condition, such as when timber harvesting is increased in areas where it had not been common in recent years, or when urban expansion occurs, can lead to costs for some people as others benefit.

  In such areas, the values of green space and large remnant forests will likely increase. Whatever the cause, the variety of effects of forest changes on local communities is likely to continue to result in controversy and an increase in local regulation of land uses and forest treatments.

- **Southern forests have proven resilient but some components are scarce and therefore vulnerable to change.** Through the 20th century, the South has recovered from a largely cutover, exhausted, and eroded condition to become one of the most productive forest regions in the world. However, the presence of numerous imperiled animal species and increasingly rare forest communities are reasons for concern. Such forest communities include: certain wetland types, longleaf pine ecosystems, old-growth forests, and spruce-fir forests. These communities are likely to continue to be adversely affected to varying degrees by multiple forces of change. Protection and restoration efforts, already underway in some of these communities, are a means of addressing these changes.

- **Scarce forest types have high ecological value**. To borrow the adage from economics, scarcity defines value. The rare forest communities in the South (above) have especially high ecological value. Thus, much consideration of biodiversity is focused on a relatively small share of the forest landscape. With the exception of old-growth and spruce-fir communities, these rare communities are largely on private land.

  In the urbanizing areas of the South, unfragmented forest cover is becoming increasingly scarce, especially in the Piedmont. In these areas, the value of residual forest cover is increasing, especially as sources of outdoor recreation and as habitat for certain wildlife species. For area-sensitive wildlife species, large contiguous blocks of forest become especially valuable as refuges in areas fragmented by urbanization or other forest disturbances. In these areas, public forests provide stable blocks of contiguous forest cover, thus the conservation value of this public land, which is especially scarce in the rapidly urbanizing Piedmont and Coastal Plain

ecological regions, is very high and will increase in the future.

4.2 Subregions of Concern

Our assessment of forces of change and their potential implications for forest systems shows especially large effects in three areas of the South.

- **Southern Appalachians**- This region will be influenced by a combination of human, biological, and physical factors over the next two decades. Population growth and land-use changes will increase the human presence in many forests. Forest-based recreation demands are focused on the Southern Appalachians, and increased competition between recreation user groups is anticipated. A complex of forest health issues is also affecting all forest types in this region and has the potential to restructure forest ecosystems.
    - The spruce-fir forest community is in decline because of the balsam wooly adelgid, an exotic insect that kills high elevation firs, combined with acid deposition and ozone pollution. Here is the most extreme case of ecological decline in the South.
    - Upland hardwood types are also subject to changes from several sources. Oak decline combined with gypsy moth infestations could soon reshape forest structure by reducing oaks in the overstory. In addition, dogwood anthracnose, butternut canker, and beech bark disease will greatly reduce the distribution of their respective host trees in much of the area. Loss of these tree species along with oaks will reduce the production of both hard and soft mast and therefore impact mast-dependent wildlife species.
    - The hemlock wooly adelgid kills both the eastern and the Carolina hemlock and is currently moving down the Blue Ridge from the Shenandoah Valley. While they occupy a narrow range of sites, hemlocks influence stream microclimate in headwater reaches, so loss of this species can have disproportionate influence on the quality of water in the region. Because the Southern Appalachians are headwater areas for several developing metropolitan areas in the Piedmont, changes in water quality and water production could have important economic implications.
- **Piedmont**—Forecasts of land-use change suggest that the Piedmont, from Virginia to Georgia, will experience the greatest loss of forest area among the ecological sections in the South. Already this heavily forested region has a very low ratio of interior forest to total forest, indicating a high degree of forest fragmentation. This fragmentation is likely to continue as the populations of urban counties and interspersed rural counties continue to grow. As a result, wildlife habitats will be altered for certain key bird species including Neotropical migrants. Fragmentation, combined with invasive exotic plants and an increased human presence will tend to alter the ecological values of forests in this region. Because populations will grow and forest area will decline, we also expect an increasing scarcity of forest-based recreational opportunities for city dwellers.

- **Lower Atlantic and Gulf Coastal Plains—** Coastal flatwoods areas are also forecast to lose large shares of forest to urban development. Forest loss combined with intensified forest management could have cumulative negative effects on coastal wetlands through direct wetland loss and modification of hydrological regimes. The flatwoods are one of two areas with the highest concentration of endangered animal and plant species in the South. They contain many imperiled amphibians, crustaceans, and reptiles.

- **Florida Panhandle**—This area of coastal flatwoods has especially high concentrations of critically imperiled species and forces of change. In the Panhandle, we anticipate a rapid increase in population and development spreading from central Florida. Intensive forest management and agricultural uses already dominate the rural landscape. This area is a hot spot for imperiled species, especially aquatic species. High rates of species endemism, especially among amphibians, suggest that wetlands and other wet habitats in this area have very high ecological value and that local actions could have far-reaching implications for species persistence.

4.3 Implications for ongoing programs

Monitoring. The crux of sustainability is to understand change and respond to it. It is, therefore, imperative to have timely data with which to gauge changes in forest conditions. As the pace of change has quickened in the South, so has the standard for timeliness. Forest surveys were originally designed to track variables that changed relatively slowly. Development has quickened, harvests have doubled over the past 30 years, and planted forests have grown rapidly. More timely data, therefore, are needed. When fully implemented, ongoing changes from periodic to continuous forest inventories conducted by the Forest Service in partnership with Southern States will address this issue.

More timely, consistent, and comprehensive data at appropriate scales also are needed for monitoring water quality, wetland modification and loss, and wetland restoration.

Delivery of Forestry Assistance. The changing demographics of forest landowners suggest changing preferences and management objectives for private forests. Many private tracts are in the "wildland-urban interface." It seems clear that nonindustrial private forest landowners, especially in the urbanizing eastern portion of the region will need a broad range of silvicultural options and assistance now and in the future.

Public Land. Demands for forest-based recreation opportunities are expanding rapidly. Private land is becoming less accessible for these kinds of activities so public land is coming under increasing pressure to supply a broad variety of recreation opportunities. Innovative management is needed to deal with increased recreation, to reduce competition between recreation groups, and to mitigate resource damages.

In some parts of the South, public land provides islands of interior forest habitat. These habitats have very high and increasing ecological value as refuges for rare species.

4.4 Knowledge Gaps and Scientific Uncertainties

As with any endeavor of this scope, an assessment of knowledge identifies the extent of our ignorance. Available information has allowed us to identify several emerging issues about the sustainability of southern forests, but additional information is needed to refine understanding and more clearly identify problems and solutions. Each chapter in the Technical Report identifies key uncertainties in specific topic areas. The following are some key issues that cut across the various topic areas:

- **Expanding populations and impacts on ecosystems**. More heavily populated rural and urban landscapes will impact wildlife, water, and other benefits derived from forested ecosystems in the South. Additional information is needed to reduce uncertainties regarding: (1) forecasts of how and where these changes might occur, (2) how human population density influences forest ecosystems and options for their management, and (3) how development can be designed to promote forest sustainability.

- **Markets, management, and values**. Because private landowners control most southern forests, forest conditions are determined by private management choices. These choices are heavily influenced by markets for forest goods and services and by other values derived from forests. A full accounting and understanding of how values are formed and how decisions are made is crucial for clarifying how forest uses and the flow of benefits will change in the future.

- **Forest Productivity**. The productivity of forest ecosystems is a key factor in determining land allocation, forest use, and ultimately forest conditions across the South. Productivity extends beyond timber production to include the provision of wildlife, clean water, and other benefits of forests, and is influenced to uncertain degrees by several forces of change.

- **Forecasting ecological changes**. This Assessment has highlighted the multiple forces of change at work in the South's forests. Yet tools are not available for: (1) forecasting the implications of these multiple, interacting changes on the area, structure, and function of southern forest ecosystems, and (2) fully understanding the impacts on values that are derived from these systems. Such tools would help identify emerging scarcities within the region.

- **Analysis at landscape and regional scales**. Science and management conducted at these broad scales are relatively new endeavors. Most forest research has been conducted at very fine scales, often without the information needed to develop implications at broader scales. When the scale at which the science is conducted does not match the questions that are being asked, answers are often incomplete.

- **Fire ecology and management**. Elimination of natural fire cycles is one of the most substantial alterations imposed by humans on the forested ecosystems of the South. Uncertainties exist regarding: (1) the role of fire in specific ecotypes, and (2) strategies for effectively and safely reintroducing fire into forest ecosystems.

- **Pine plantations and ecosystem functions**. Some portions of the South will see increased concentrations of pine plantations. Landscape-level ecological implications of increased pine plantations are uncertain. Additional information on the wildlife implications of expanding pine plantations is needed, especially in the Coastal Plain of Georgia, Alabama, Florida, and Mississippi.

- **Forest management approaches**. This Assessment has described an increasingly complex environment for conducting forest management and suggests a need for a broader array of management strategies. New management approaches are especially needed for managing forests in "wildland-urban interface" areas.